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ANCHOR QEA

Elliott Bay Seawall Project: 2018 Post Construction Monitoring Report (Year 1)

City of Seattle Department of Transportation

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ABBREVIATIONS

#/m^2	number per square meter
Aquarium	Seattle Aquarium
cm	centimeter
EBSP	Elliott Bay Seawall Project
HIZ	habitat intertidal zone
LPS	light penetrating surface
LS	lower shelf
LW	lower wall
MLLW	mean lower low water
NAVD88	North American Vertical Datum 1988
PAR	photosynthetically active radiation
Report	*Elliott Bay Seawall Project: 2018 Post Construction Monitoring Report (Year 1)*
SDOT	Seattle Department of Transportation
US	upper shelf
UW	upper wall

Executive Summary

The Elliott Bay Seawall Project (EBSP) is being constructed by the City of Seattle Department of Transportation. This *Elliott Bay Seawall Project: 2018 Post Construction Monitoring Report (Year 1)* (Report) is being prepared as required by the U.S. Army Corps of Engineers Individual Permit (Permit No. NWS 2011-778-WRD) and associated Biological Opinion, Washington Department of Ecology Section 401 Water Quality Certification (Order No. 9829), Washington Department of Fish and Wildlife Hydraulic Project Approval (No. 126724 and subsequent modifications), Washington Department of Natural Resources Right of Entry (No. 23-090259), and the City of Seattle Shoreline Substantial Development Permit (Permit No 3013171). The EBSP extends more than 7,000 linear feet along the eastern shoreline of Elliott Bay in Seattle, Washington, between the northern edge of Pier 48 to the south and Pier 70 to the north. The currently constructed portion of the seawall extends approximately 3,100 feet from Washington State Ferries' Colman Dock to north of the Seattle Aquarium. Construction of the habitat intertidal zone (formerly Zone 1 habitat beach) located south of Colman Dock and habitat features at Pier 62/63 are anticipated to be completed by February 2019. The north seawall work is not yet funded for design or construction.

This Report presents the results of the Year 1 post construction monitoring as identified in the E*BSP Post Construction Monitoring and Adaptive Management Plan* (Tetra Tech 2013) and the *EBSP Post Construction Monitoring and Adaptive Management Plan Update* (SDOT 2017). Habitat enhancement features that were monitored for this Report include light penetrating surfaces (LPS) in the cantilevered sidewalks, textured seawall surface with shelves or fins, intertidal habitat benches (marine mattresses), and gravel substrate enhancement.

This Report presents the methods and results for the following EBSP Year 1 monitoring activities:

- Invertebrate and algal attachment on the textured seawall (Section 2)
- Macroalgae growth under LPS (Section 3)
- Bull kelp (*Nereocystis luetkeana*) distribution and density (Section 4)
- Corridor physical characteristics (Section 5)
- Invertebrate colonization of benches (habitat beach construction not completed; Section 6)
- Illumination (Section 6)
- Salmon presence and behavior (Section 6)

Table E-1 presents the EBSP monitoring plan restoration targets, followed by a summary of results. As described in Table E-1, several construction elements are not complete or have not yet begun and most restoration target schedules occur during future monitoring years. The findings in this Year 1 Report should be considered preliminary. Monitoring reports with statistical analysis and interpretation will be completed during future years of monitoring.

Table E-1
Elliott Bay Seawall Project Nearshore Habitat Enhancement Objectives and Restoration Targets

Restoration Target	Schedule	Status
Objective 1: Create an effective intertidal migratory corridor for juvenile salmonids		
Increase illumination behind piers and below cantilevered sidewalks to increase light levels within the proposed intertidal corridor and diminish light/dark transitions as compared to existing conditions.	Immediately after replacement of the sidewalk and installation of LPS	Phase 1 construction elements completed; light levels ranged from 1.4 to 6.1 times higher than piers without LPS.
Create a continuous intertidal corridor at appropriate depth (~0 feet mean lower low water) for juvenile salmon migration along the entire length of the project.	Immediately after construction	Phase 1 construction elements completed; overall densities for all fish including juvenile salmon were highest at seawall and Olympic Sculpture Park habitat bench sites suggesting that relatively high numbers of fish can benefit from habitat enhancements at these habitats.
Achieve colonization of the loose substrate habitat benches and Zone 1 bench/beach by salmonid prey species.	Within 5 years after construction	In progress in Year 1; Zone 1 currently under construction.
Observe statistical increase in presence of juvenile salmonids within the intertidal migratory corridor.	Within 3 years after construction	In progress in Year 1; statistical analysis pending, initial indications are a proportion of the juvenile salmon along the seawall are using the corridor under the piers lit by LPS.
Objective 2: Enhance the marine nearshore ecosystem quality and function		
Increase invertebrate and algal density and diversity on shelves/textured wall vs. flat seawall.	Statistically comparable to Goff (2010) results from panel experiments with stable density/diversity by Year 5 after construction	In progress in Year 1; the textured seawall is providing suitable attachment locations for multiple invertebrate and algal species.
Provide sufficient illumination to allow macroalgae to grow underneath cantilevered sidewalk and behind piers and also increase invertebrate diversity/density as compared with shaded under-pier locations.	Achieve 30% increased density/diversity under the cantilevered sidewalk by Year 5 and 15% increased density/diversity behind the piers as compared to a control shaded pier site	In progress in Year 1; a variety of macroalgae species were observed in uncovered areas and fewer species were observed in areas behind piers.
Provide suitable substrate for crab and other invertebrate colonization on the substrate enhancement sites as compared with adjacent silt/shell hash substrate.	Within 3 years of construction	In progress in Year 1; the substrate enhancement sites are providing suitable habitat for crab and other invertebrate species.

Restoration Target	Schedule	Status
Provide sustainable riparian zone on upper area of Zone 1 beach/bench.	Within 3 years of construction achieve and maintain 80% cover of native tree, shrub, and herbaceous species	Zone 1 currently under construction.
Provide increased terrestrial insect input in areas of riparian vegetation as compared to areas without riparian vegetation.	Achieve minimum 10% increase at vegetated sites within 5 years compared to unvegetated sites	Zone 1 currently under construction; Phase 2 currently not funded.
Increase kelp distribution and density by 10 percent (averaged across entire survey area) as compared to pre-construction conditions.	Within 3 years of construction	In progress in Year 1; bull kelp presence and density were lower throughout study area (including reference site) than what was documented in the 2010 survey.

1 Introduction

The Elliott Bay Seawall Project (EBSP) is being constructed by the City of Seattle Department of Transportation (SDOT). This *Elliott Bay Seawall Project: 2018 Post Construction Monitoring Report (Year 1)* (Report) is being prepared as required by the U.S. Army Corps of Engineers Individual Permit (Permit No. NWS 2011-778-WRD) and associated Biological Opinion, Washington Department of Ecology Section 401 Water Quality Certification (Order No. 9829), Washington Department of Fish and Wildlife Hydraulic Project Approval (No. 126724 and subsequent modifications), Washington Department of Natural Resources Right of Entry (No. 23-090259), and the City of Seattle Shoreline Substantial Development Permit (Permit No 3013171). The EBSP extends more than 7,000 linear feet along the eastern shoreline of Elliott Bay in Seattle, Washington, between the northern edge of Pier 48 to the south and Pier 70 to the north. The currently constructed portion of the seawall extends approximately 3,100 feet from Washington State Ferries' Colman Dock to north of the Seattle Aquarium (Aquarium). Construction of the habitat intertidal zone (HIZ; formerly Zone 1 habitat beach) located south of Colman Dock and habitat features at Pier 62/63 is anticipated to be completed by February 2019. The north seawall work is not yet funded for design or construction. A vicinity map is shown in Figure 1 and an aerial photograph of the EBSP area is shown in Figure 2.

The *EBSP Post Construction Monitoring and Adaptive Management Plan* (Tetra Tech 2013) and the *EBSP Post Construction Monitoring and Adaptive Management Plan Update* (SDOT 2017) identifies the monitoring activities to evaluate the effectiveness of the habitat enhancement features that were established as part of the EBSP to create an effective intertidal migratory corridor for juvenile salmonids and enhance the marine nearshore ecosystem.

This Report presents the results of the Year 1 post construction monitoring as identified in the monitoring plan (Tetra Tech 2013) and the monitoring plan update (SDOT 2017). Habitat enhancement features that were established for the EBSP associated with the monitoring performed for this Report include light penetrating surfaces (LPS) in the cantilevered sidewalks, textured seawall surface with shelves or fins, intertidal habitat benches (marine mattresses), and gravel substrate enhancement.

This Report presents the methods and results for the following EBSP Year 1 monitoring activities:

- Invertebrate and algal attachment on the textured seawall (Section 2)
- Macroalgae growth under LPS (Section 3)
- Bull kelp (*Nereocystis luetkeana*) distribution and density (Section 4)
- Corridor physical characteristics (Section 5)
- Invertebrate colonization of benches (habitat beach construction not completed; Section 6)
- Illumination (Section 6)
- Salmon presence and behavior (Section 6)

The Year 1 EBSP monitoring surveys for invertebrate and algal attachment on the textured seawall, macroalgae growth under LPS, bull kelp distribution and density, and corridor physical characteristics was performed by Anchor QEA. Monitoring data from these surveys are presented in the following sections and in data tables in Appendix A. The University of Washington performed the surveys for invertebrate colonization of benches, illumination, and salmon presence and behavior. The methods, results, figures, and photographs from the *University of Washington 2018 Seawall Data Report* (University of Washington 2018) are incorporated into this Report in Section 6. Data result tables and additional survey photographs from the University of Washington Data Report are included in Appendix B. Photographs from the EBSP monitoring surveys for invertebrate and algal attachment on the textured seawall and macroalgae growth under LPS, are included in Appendix C.

2 Invertebrate and Algal Attachment on Seawall

This section presents the methods and Year 1 results of the invertebrate and algal monitoring surveys. The EBSP seawall was replaced with a textured surface and shelves to provide a diversity of surfaces as well as crevices to allow for invertebrate and algal attachment to the seawall. The Year 1 2018 invertebrate and algal monitoring was performed at two locations, the Aquarium north site and the Pier 55 site, shown in Figures 3 and 4, respectively.

The goal of the invertebrate and algal monitoring is to document the attachment and use of textured surfaces and shelves to compare to the results of the document *Evaluating Habitat Enhancements of an Urban Intertidal Seawall: Ecological Responses and Management Implications* (Goff 2010), which evaluated the invertebrate and algal growth on several seawall test panels. The overall objective of the monitoring surveys is to evaluate the various seawall habitat enhancement designs that incorporate slope and texture on a concrete vertical seawall by measuring the potential of these designs to provide microhabitat that promotes colonization of invertebrates and algae and to improve ecology of the intertidal zone in a built environment.

2.1 Methods

Year 1 invertebrate and algal monitoring was performed by Anchor QEA on April 3 and 4, June 17 and 18, and August 13 and 14, 2018. The invertebrate and algal monitoring methods followed the methods identified in the monitoring plan (Tetra Tech 2013). The following change to the invertebrate and algal monitoring methods was identified in the monitoring plan update (SDOT 2017):

- The Vine Street site was replaced by the Pier 55 site because seawall work is not yet funded for design or construction in this north area of the seawall.

As described in the monitoring plan (Tetra Tech 2013), invertebrate and algal monitoring methods generally followed Goff (2010) and included invertebrate and algal quadrat sampling on the textured wall and shelves. Quadrat sampling with 25 centimeter (cm) by 25 cm gridded quadrats was conducted at the Aquarium north site and the Pier 55 site to show variation based on orientation and wave action.

At each of the two monitoring sites (Aquarium and Pier 55) data were collected from the vertical textured wall at two areas, an uncovered area (between piers) and a covered area (behind piers). At each covered and uncovered area data were collected along three transects. Along each transect four quadrats were located as follows beginning at the higher elevation on the wall:

- Upper wall (UW) at +2.2 meters mean lower low water (MLLW)
- Upper shelf (US)
- Lower wall (LW) at +1.2 meters MLLW
- Lower shelf (LS)

With three transects and four survey quadrats per transect there are 12 survey quadrats each per covered and uncovered area, equaling 24 total survey quadrats per monitoring site, or 48 total quadrats surveyed. The quadrats were scanned visually, and all invertebrates and algae within each grid cell was identified. Percent-cover was estimated for the entire quadrat. Photographs of each quadrat were also taken to document conditions during the survey. Due to the elevation of +2.2 meters MLLW, the UW quadrat locations were located more than 2 meters above the bench surface, making individual grid cell surveying impossible. As a result, species presence and percent-cover were estimated for the entire quadrat based on a visual scan made from a distance of a few feet. In addition, due to the height and the angle of the US, on some shelves visibility of the upper row of quadrat grid cells was restricted. As described below in the results section, species presence and diversity were higher on the LW and LS than the UW and US so the quadrats with restricted visibility were typically less diverse with less total cover. The locations of the seawall monitoring transects are identified in Photographs 1 through 4 in the Results Section.

2.2 Results

The invertebrate and algal monitoring results are summarized in the following sections. Invertebrate and algal monitoring data collected at each quadrat were entered into Microsoft Excel spreadsheets for each Aquarium north and Pier 55 monitoring site, per covered and uncovered areas. Monitoring data for each individual quadrat are presented in Tables A-1 through A-12 in Appendix A.

2.2.1 Invertebrate and Algal Species Observed

During the surveys, 20 total invertebrate and algal species or families of species were observed. The species were organized into seven groups as identified in Goff (2010). Species observed at the Aquarium north and Pier 55 monitoring sites during the April, June, and August monitoring surveys, per covered and uncovered area, are presented in Tables 1 and 2, respectively. The average percent cover of the five most commonly observed species, per monitoring location and April, June, and August monitoring surveys, are presented on the graph in Figure 5.

Table 1
Invertebrate and Algal Species Observed at the Aquarium North Site During Year 1 Monitoring

Scientific Name	Common Name	Aquarium Uncovered			Aquarium Covered		
		April	June	August	April	June	August
Sessile Invertebrates							
Balanus crenatus	Crenulated barnacle	No	No	No	No	Yes	Yes
Balanus glandula	Acorn barnacle	Yes	Yes	Yes	Yes	Yes	Yes
Chthamalus dalii	Little brown barnacle	No	No	No	No	No	No
Semibalanus cariosus	Thatched barnacle	Yes	Yes	Yes	Yes	Yes	Yes
Ascidiacea	Ascidian/Sea squirt	No	Yes	No	No	No	No

Scientific Name	Common Name	Aquarium Uncovered			Aquarium Covered		
		April	June	August	April	June	August
Bryozoan	Bryozoan	No	No	No	Yes	Yes	Yes
Mytilus sp.	Mussels	Yes	Yes	Yes	Yes	Yes	Yes
Tube worms	Tube worms	No	No	No	No	No	No
Mobile Invertebrates							
Lottia pelta	Shield limpet	Yes	Yes	Yes	No	Yes	Yes
Tectura scutum	Plate limpet	Yes	No	Yes	No	No	No
Littorins sp.	Snails/Periwinkles	Yes	No	Yes	No	No	No
Mopalia muscosa	Mossy chiton	No	No	No	No	No	No
Foliose algae							
Porphyra sp1	Red algae	No	No	No	No	No	No
Porphyra sp2	Red algae	Yes	Yes	Yes	No	No	No
Ulva linza	Green string lettuce	Yes	Yes	Yes	No	No	Yes
Ulva sp.	Sea lettuce	Yes	Yes	Yes	No	No	No
Filamentous algae							
Bangia sp.	Red hair	Yes	No	No	No	No	No
Corticated macrophytes							
Mastocarpus papillatus	Black tar	Yes	Yes	Yes	Yes	No	Yes
Leathery macrophytes							
Fucus disticus	Rockweed	Yes	Yes	Yes	No	No	No
Microalgae							
Biofilm	Diatoms, bacteria	No	No	Yes	No	No	Yes

Table 2
Invertebrate and Algal Species Observed at the Pier 55 Site During Year 1 Monitoring

Scientific Name	Common Name	Pier 55 Uncovered			Pier 55 Covered		
		April	June	August	April	June	August
Sessile Invertebrates							
Balanus crenatus	Crenulated barnacle	No	No	Yes	Yes	Yes	Yes
Balanus glandula	Acorn barnacle	Yes	Yes	Yes	Yes	Yes	Yes
Chthamalus dalii	Little brown barnacle	Yes	Yes	Yes	No	Yes	Yes
Semibalanus cariosus	Thatched barnacle	Yes	Yes	Yes	Yes	Yes	Yes
Ascidiacea	Ascidian/Sea squirt	No	Yes	No	No	Yes	No
Bryozoan	Bryozoan	No	No	Yes	Yes	No	Yes
Mytilus sp.	Mussels	Yes	Yes	Yes	Yes	Yes	Yes
Tube worms	Tube worms	No	No	No	Yes[1]	No	No
Mobile Invertebrates							

Scientific Name	Common Name	Pier 55 Uncovered			Pier 55 Covered		
		April	June	August	April	June	August
Lottia pelta	Shield limpet	No	No	Yes	No	No	Yes
Tectura scutum	Plate limpet	Yes	Yes	Yes	Yes	Yes	No
Littorins sp.	Snails/Periwinkles	No	No	No	No	No	Yes
Mopalia muscosa	Mossy chiton	No	No	No	No	Yes	No
Foliose algae							
Porphyra sp1	Red algae	Yes	Yes	Yes	No	No	No
Porphyra sp2	Red algae	No	Yes	No	No	No	No
Ulva linza	Green string lettuce	Yes	Yes	Yes	No	No	Yes
Ulva sp.	Sea lettuce	Yes	Yes	Yes	No	No	Yes
Filamentous algae							
Bangia sp.	Red hair	Yes	Yes	Yes	No	No	No
Corticated macrophytes							
Mastocarpus papillatus	Black tar	Yes	Yes	Yes	No	Yes	Yes
Leathery macrophytes							
Fucus disticus	Rockweed	No	No	Yes	No	No	No
Microalgae							
Biofilm[2]	Diatoms, bacteria	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. Tube worm observations were empty casings
2. Biofilm covers bare areas and species

2.2.2 Invertebrates and Algae Observed at Uncovered Areas

2.2.2.1 April Monitoring

During the April monitoring at the uncovered areas of the Aquarium north and the Pier 55 sites acorn barnacle (*Balanus glandula*) was the most common species observed, occurring within all 24 quadrats. Thatched barnacle (*Semibalanus cariosus*) was the second most common species.

Additional frequently observed species at the Aquarium north site included mussels (*Mytilus* sp.) and black tar (*Mastocarpus papillatus*). Shield limpet (*Lottia pelta*) was also frequently observed at the Aquarium north site, and plate limpet (*Tectura scutum*) was frequently observed at the Pier 55 uncovered site. Biofilm was also frequently observed at the Pier 55 site, covering bare surfaces and invertebrate species. No biofilm was observed at the Aquarium north site.

Algae species were generally infrequent, with species such as sea lettuce (*Ulva* sp.) and green string lettuce (*Ulva linza*) occurring in a few Aquarium north and Pier 55 quadrats. The Aquarium north and Pier 55 uncovered monitoring areas are shown in Photographs 1 and 2. Examples of the April monitoring Aquarium north and Pier 55 uncovered quadrats are shown in Photographs in Appendix C.

Photograph 1
August Monitoring Aquarium North Site Uncovered Monitoring Area

Photograph 2
August Monitoring Pier 55 Site Uncovered Monitoring Area

2.2.2.2 June Monitoring

During the June monitoring at the uncovered areas of the Aquarium north and the Pier 55 sites, common species observed were similar to the April observations, but species variety and density increased. Acorn barnacle was the most common species occurring within 23 of 24 quadrats and thatched barnacle also occurred in most of the quadrats.

At the Aquarium north site, mussels were observed in all 12 Aquarium north quadrats and half of the Pier 55 quadrats. Shield limpet was observed in most of the Aquarium north quadrats, and plate limpet was observed in most of the Pier 55 quadrats. Black tar was frequently observed at both the Aquarium north and Pier 55 sites. Biofilm was again covering bare surfaces and invertebrate species in a majority of the Pier 55 site and was not observed at the Aquarium north site.

Algae species presence increased during the June monitoring at both the Aquarium north and Pier 55 sites with sea lettuce and green string lettuce occurring in almost half of the quadrats. Examples of the June monitoring Aquarium north and Pier 55 uncovered quadrats are shown in the photographs in Appendix C.

2.2.2.3 August Monitoring

During the August monitoring at the uncovered areas of the Aquarium north and the Pier 55 sites, common species observed were similar to the April and June observations and there was an overall continued increase of species variety and density. Acorn barnacle was the most common species occurring within all 24 quadrats, and thatched barnacle occurred in most of the quadrats.

At the Aquarium north site, mussel presence decreased from the June surveys, occurring in 6 of the 12 quadrats. Shield limpet was observed in 10 of the Aquarium north quadrats and all 12 of the Pier 55 quadrats. Black tar was observed in all 12 of the Aquarium north quadrats and 7 of the Pier 55 quadrats. Biofilm was covering bare surfaces and invertebrate species in half of the Pier 55 quadrats and was observed in one of the Aquarium north quadrats.

Algae species presence during the August monitoring was generally similar to the June observations at both the Aquarium north and Pier 55 sites with green string lettuce occurring in almost half of the quadrats and sea lettuce occurring in all 12 of the Pier 55 quadrats and 1 of the Aquarium north quadrats. Examples of the August monitoring Aquarium north and Pier 55 uncovered quadrats are shown in Photographs in Appendix C.

2.2.3 Invertebrates and Algae Observed at Covered Areas

2.2.3.1 April Monitoring

Low species diversity and density were observed during the April monitoring at the covered areas of the Aquarium north and the Pier 55 sites. Acorn barnacle was the most common species observed,

occurring within all 24 quadrats. Crenulated barnacle (*Balanus crenatus*) was observed in eight of the Pier 55 quadrats. At the Aquarium north site, mussels were observed in nine of the quadrats.

Biofilm was observed in five of the Pier 55 quadrats, covering bare surfaces and invertebrate species. No biofilm was observed at the Aquarium north site.

Algae species were absent in the covered areas with the exception of red algae (*Porphyra* sp1) observed in one of the Pier 55 quadrats. The Aquarium north and Pier 55 covered monitoring areas are shown in Photographs 3 and 4. Examples of the April monitoring Aquarium north and Pier 55 covered quadrats are shown in Photographs in Appendix C.

Photograph 3
August Monitoring Aquarium North Site Covered Monitoring Area

Photograph 4
August Monitoring Pier 55 Site Covered Monitoring Area

2.2.3.2 June Monitoring

During the June monitoring at the covered areas of the Aquarium north and the Pier 55 sites, invertebrate species diversity and density increased from the April surveys. Acorn barnacle was observed within all 24 quadrats and several additional sessile invertebrate species were observed within both the Aquarium north and Pier 55 sites. Little brown barnacle (*Chthamalus dalii*) was observed in three of the Pier 55 quadrats.

Bryozoan was present in seven of the Aquarium north quadrats. Sea squirt (*Ascidiacea*) was present in four of the Pier 55 quadrats. Biofilm presence was similar to what was observed during the April surveys. No algae species were observed at either the Aquarium north or Pier 55 sites. Examples of the June monitoring Aquarium north and Pier 55 covered quadrats are shown in Photographs in Appendix C.

2.2.3.3 August Monitoring

During the August monitoring at the covered areas of the Aquarium north and the Pier 55 sites, species variety and density increased from the June observations. Acorn barnacle continued to be the most common species occurring within all 24 quadrats. Crenulated barnacle, little brown

barnacle, and thatched barnacle were observed in several of the Aquarium north and Pier 55 sites. Bryozoan was present in a majority of both the Aquarium north and Pier 55 quadrats.

Shield limpet was observed in seven of the Aquarium north quadrats and six of the Pier 55 quadrats. Black tar was observed in four of the Aquarium north quadrats and nine of the Pier 55 quadrats. Biofilm was covering bare surfaces and invertebrate species in three of the Pier 55 quadrats and one of the Aquarium north quadrats.

Algae species presence during the August monitoring was infrequent with green string lettuce occurring in two of the Aquarium north quadrats and one of the Pier 55 quadrats. Sea lettuce was observed in four of the Pier 55 quadrats. Examples of the August monitoring Aquarium north and Pier 55 covered quadrats are shown in Photographs in Appendix C.

2.2.4 Comparison to 2008/2009 Surveys

The majority of invertebrate and algal species observed during the Year 1 monitoring surveys are documented in the 2008/2009 surveys performed during the seawall test panel sampling, as identified in Table 1.5 of the Goff report (2010).

Acorn barnacles were the dominant barnacle observed during the 2008/2009 and the Year 1 surveys. Crenulated barnacle, little brown barnacle, and thatched barnacle were additional barnacle species observed during both surveys. Limpet presence was low during April surveys and increased during June and August monitoring during both the 2008/2009 and Year 1 surveys. Mussel presence also increased between April, June, and August during both the 2008/2009 and Year 1 surveys.

Red algae (*Porphyra* sp1 and *Porphyra* sp2) species and rockweed (*Fucus disticus*) were observed more frequently during the 2008/2009 surveys than during the Year 1 surveys. Green string lettuce, sea lettuce, black tar, and biofilm were frequently observed during both the 2008/2009 and Year 1 surveys.

3 Macroalgae Growth under the Light Penetrating Surfaces

This section presents the methods and Year 1 results of the macroalgae growth on habitat benches under the LPS monitoring surveys. The LPS in the cantilevered sidewalks are designed to allow illumination for potential macroalgae growth and survival. The Year 1 2018 macroalgae growth monitoring was performed at two locations, the Aquarium north site and the Pier 55 site, shown in Figures 3 and 4, respectively.

3.1 Methods

Year 1 macroalgae growth monitoring was performed by Anchor QEA on April 3 and 4, June 17 and 18, and August 13 and 14, 2018. The macroalgae growth monitoring methods followed the methods identified in the monitoring plan (Tetra Tech 2013), with the following changes proposed in the monitoring plan update (SDOT 2017):

- The Vine Street site was replaced by the Pier 55 site because seawall work is not yet funded for design or construction in this north area of the seawall.
- Monitoring at the Pier 62/63 site was not sampled during Year 1 because construction was ongoing during 2018 at this location.
- Monitoring at the Pier 69 site was not performed because seawall work is not yet funded for design or construction in this north area of the seawall.
- Monitoring was performed in August but not April and June because August represents peak macroalgae growth and is consistent with previous University of Washington macroalgae studies.

Quadrat sampling (25-cm by 25-cm gridded quadrats) was conducted at the Aquarium north site and the Pier 55 site similar to sampling described in Section 2 for the invertebrate and algal monitoring. Macroalgae data were collected with five quadrats placed from the seawall across the bench at each uncovered area (between piers) and covered area (behind piers) at each of the two monitoring sites. The quadrats were scanned visually, and all algae within each grid cell was identified. Percent-cover was estimated for the entire quadrat. Macroalgae data were also collected with five randomly placed quadrats at the expanded bench at the Aquarium north site. Photographs of quadrats were also taken to document conditions during the survey. While quadrat sampling was not performed during the April and June monitoring activity per the monitoring plan update (SDOT 2017), anecdotal observations of macroalgae presence was collected during the April and June invertebrate and algal monitoring activities. The locations of the monitoring transects on the benches are identified in Photographs 5 through 8 in the Results Section.

3.2 Results

The macroalgae growth monitoring results are summarized in the following sections. Anecdotal observations of macroalgae presence documented during the April and June invertebrate and algal

monitoring activities are also provided in the following sections. Macroalgae growth monitoring data collected at each quadrat were entered into Microsoft Excel spreadsheets for each Aquarium north and Pier 55 monitoring site, per covered and uncovered areas. Monitoring data for each individual quadrat are presented in Tables A-13 through A-16 in Appendix A.

3.2.1 Macroalgae Species Observed

Macroalgae growth observation data for all monitoring quadrats are provided in Appendix A. During the surveys, nine total macroalgae species or families of species were observed. The species were organized into four groups as identified in Goff (2010). Species observed at the Aquarium monitoring site during the August monitoring surveys, per covered and uncovered area, are presented in Table 3. Species observed at the Pier 55 monitoring site during the August monitoring surveys, per covered and uncovered area, are presented in Table 4. The average percent cover of the five most commonly observed species, per monitoring location during the August monitoring surveys, are presented on the graph in Figure 6.

Table 3
Macroalgae Species Observed at the Aquarium North Site During Year 1 August Monitoring

Scientific Name	Common Name	Aquarium Uncovered Bench	Aquarium Uncovered Expanded Bench	Aquarium Covered Bench	Aquarium Covered Expanded Bench
Foliose algae					
Porphyra sp1	Red algae	No	No	No	No
Porphyra sp2	Red algae	No	No	No	No
Ulva linza	Green string lettuce	No	Yes	No	No
Ulva sp.	Sea lettuce	Yes[1]	Yes[1]	Yes[1]	No
Filamentous algae					
Bangia sp.	Red hair	No	No	No	No
Corticated macrophytes					
Mastocarpus papillatus	Turkish washcloth	Yes	Yes	No	No
Mazaella splendens	Iridescent weed	No	Yes	No	No
Leathery macrophytes					
Costaria costata	Five-ribbed kelp	No	No	No	No
Fucus disticus	Rockweed	No	No	No	No

Note:
1. Both attached and unattached macroalgae observed

Table 4
Macroalgae Species Observed at the Pier 55 Site During Year 1 August Monitoring

Scientific Name	Common Name	Pier 55 Uncovered Bench	Pier 55 Covered Bench
Foliose algae			
Porphyra sp1	Red algae	no	no
Porphyra sp2	Red algae	no	no
Ulva linza	Green string lettuce	no	no
Ulva sp.	Sea lettuce	yes[1]	no
Filamentous algae			
Bangia sp.	Red hair	yes	yes
Corticated macrophytes			
Mastocarpus papillatus	Turkish washcloth	yes	no
Mazaella splendens	Iridescent weed	yes	no
Leathery macrophytes			
Costaria costata	Five-ribbed kelp	no	no
Fucus disticus	Rockweed	no	no

Note:

1. Both attached and unattached macroalgae observed

3.2.2 Macroalgae Observed at Uncovered Areas

At the uncovered areas of the Aquarium north and the Pier 55 sites, sea lettuce was the most common species observed during the August monitoring, occurring within each of the survey quadrats. Sea lettuce was also observed within each quadrat of the Aquarium north site expanded bench. Both attached and unattached sea lettuce was observed within the quadrats and in the area around the quadrats.

Turkish washcloth (*Mastocarpus papillatus*) was also observed at the benches of both sites and on the expanded bench of the Aquarium north site. Iridescent weed (*Mazaella splendens*) was observed at the bench of the Pier 55 site and on the expanded bench of the Aquarium north site. Green string lettuce was observed on the expanded bench of the Aquarium north site and red hair (*Bangia* sp.) was observed at the Pier 55 site.

Additional attached and unattached species observed outside the quadrats at the Aquarium north and the Pier 55 sites included two species of red algae (*Porphyra* sp1 and *Porphyra* sp2), rockweed, and five-ribbed kelp (*Costaria costata*). Examples of the August monitoring Aquarium north and Pier 55 uncovered bench quadrats are shown in Photographs in Appendix C. The Aquarium north and Pier 55 uncovered bench monitoring areas are shown in Photographs 5 and 6.

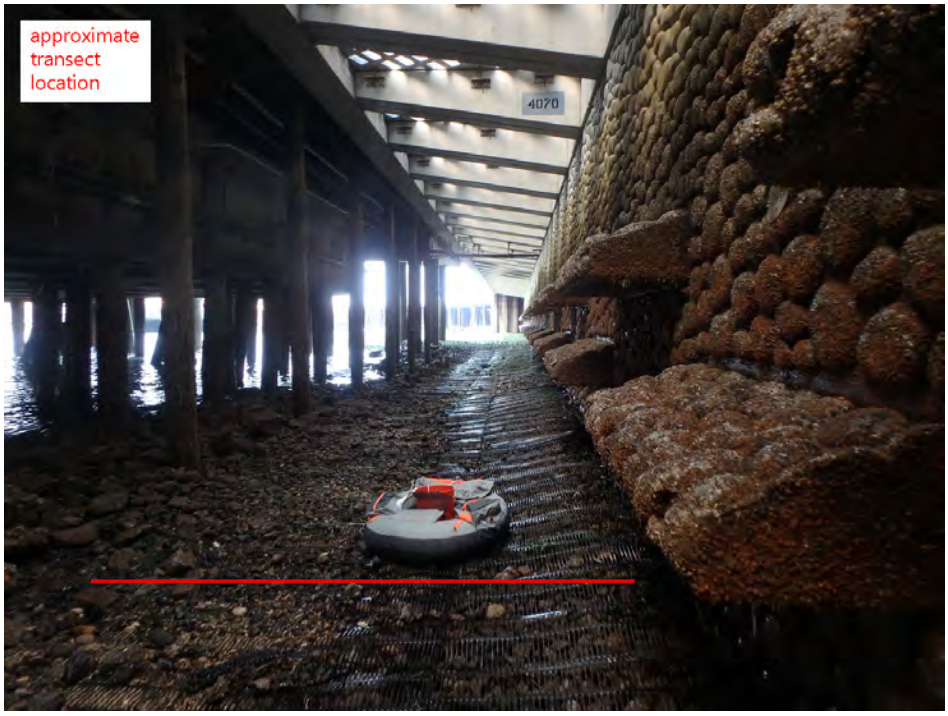
Photograph 5
August Monitoring Aquarium North Site Uncovered Bench Monitoring Area

Photograph 6
August Monitoring Pier 55 Site Uncovered Bench Monitoring Area

3.2.3 Macroalgae Observed at Covered Areas

Two species were observed at the covered areas of the Aquarium north and the Pier 55 sites. Unattached sea lettuce was observed within two quadrats of the Aquarium north site and red hair was observed within two quadrats of the Pier 55 site. No macroalgae was observed at the Aquarium north site expanded bench. Examples of the August monitoring Aquarium north and Pier 55 covered bench quadrats are shown in Photographs in Appendix C. The Aquarium north and Pier 55 covered bench monitoring areas are shown in Photographs 7 and 8.

Photograph 7
August Monitoring Aquarium North Site Covered Bench Monitoring Area



Photograph 8
August Monitoring Pier 55 Site Covered Bench Monitoring Area

3.2.4 Macroalgae Observed During April and June Monitoring

Although quadrat sampling was not performed during the April and June monitoring activity per the monitoring plan update (SDOT 2017), several macroalgae species were observed on the uncovered benches during the April and June invertebrate and algal monitoring activities. No macroalgae species were observed on the covered benches during the April and June monitoring.

Attached and unattached macroalgae observed during the April monitoring at the uncovered area of the Aquarium north and Pier 55 sites included two species of red algae, sea lettuce, and rockweed. Red hair was also observed at the Pier 55 site.

Attached and unattached macroalgae observed during the June monitoring at the uncovered Aquarium north and the Pier 55 sites included two species of red algae, sea lettuce, red hair, five-ribbed kelp, and rockweed. Green string lettuce was observed at the Aquarium north site and Turkish washcloth and iridescent weed was observed at the Pier 55 site.

4 Bull Kelp Distribution and Density

This section presents the methods and Year 1 results of the bull kelp survey. The southern margin of the bull kelp survey area was the open area south of Pier 48. The northern margin was the north end of the pocket beach in Olympic Sculpture Park. This survey area extends slightly north and south of the EBSP area. The Olympic Sculpture Park portion of shoreline provides a good reference site because the construction of the park in 2008 included the placement of low intertidal and shallow subtidal rock material to support bull kelp colonization. The bull kelp survey area and results are shown in Figures 7 through 10.

The patch size, distribution, and number of stipes were compared to the 2010 results of the *Shoreline Survey of Bull Kelp Distributions along Elliott Bay Seawall Project Area Memorandum* (Anchor QEA 2010).

4.1 Methods

Year 1 bull kelp monitoring was performed by Anchor QEA on September 13, 2018. Bull kelp monitoring was performed as identified in the monitoring plan (Tetra Tech 2013). No changes to the bull kelp monitoring were proposed in the monitoring plan update (SDOT 2017).

Data were collected during tide levels between +3.0 and +6.5 feet MLLW. A visual observation of bull kelp distribution and density was conducted by boat and while walking the downtown Seattle Waterfront shoreline and publicly accessible pier areas along the entire length of the seawall. This technique only identified bull kelp visible on the surface of the water. This technique can be a conservative estimate of the distribution and abundance of bull kelp in the survey area.

Kelp blade stipes were visually counted, and the perimeter of each bed was mapped using GPS and by marking up an aerial image of the shoreline. Information was recorded on the approximate bull kelp patch location and shape. Bull kelp distribution is variably patchy within each of the polygons identified. To provide information on the abundance of bull kelp in each polygon, the number of stipes (i.e., stems) in each patch was counted and recorded.

4.2 Results

Figures 7 through 10 depict the bull kelp distributions along the survey area and show the 2010 and Year 1 results for comparison. Bull kelp was observed along the shoreline areas between the piers present along the waterfront. Seven patches of 10 or more stipes were observed between Pier 70 and Pier 48 during the Year 1 survey compared to 14 during the 2010 survey. The largest patches were observed in the northern portion of the EBSP (i.e., north of Pier 66) and between the Seattle Aquarium and Pier 62/63.

Fewer patches were observed during the Year 1 survey compared to the 2010 survey results (Anchor QEA 2010), as shown in Figures 7 through 10. In addition to the reduction in patches, there

was an overall decrease in the number of bull kelp observed between the 2010 and Year 1 surveys. The decrease in bull kelp patches between the Year 1 and 2010 surveys occurred throughout the bull kelp study area including within the existing EBSP area (Colman Dock to north of the Aquarium), the EBSP area where construction had yet to begin (south of Colman Dock to Pier 48), outside the existing EBSP area (Pier 62/63 north to Pier 70), and along the Olympic Sculpture Park shoreline portion of the survey area (north of Pier 70).

A variety of recent and current research in Puget Sound has documented a decrease in bull kelp presence in recent years. Examples of some of the ongoing research into the bull kelp declines includes the following:

- *Kelp Continues Steady Decline in Puget Sound* (Encyclopedia of Puget Sound 2018a)
- *Puget Sound Science Review: Kelp* (Encyclopedia of Puget Sound 2018b)
- *Kelp Continues Steady Decline in Puget Sound* (Puget Sound Institute 2018)
- *Puget Sound Restoration Fund: Kelp Restoration* (Puget Sound Restoration Fund 2018)
- *Monitoring Salish Sea Bull Kelp (Nereocystis luetkeana) via Kayak Surveys* (Salish Sea Ecosystem Conference 2018)

Based on existing research, in general, multiple factors working in concert are the likely cause for bull kelp declines. The following potential factors have been identified for declines of bull kelp in Puget Sound:

- Temperature has been found to be a key factor in spore production and survival, which could be increasingly threatened by climate change.
- Sediment can bury the tiny gametophytes and reduce light levels needed for germination.
- Shoreline alterations can eliminate rocks and substrate for kelp to hold onto.
- Toxic pollution could inhibit growth and development.
- Getting eaten can occur at any time during the kelp's life cycle.

Overall, bull kelp patches and numbers of bull kelp showed significant decreases between the 2010 and Year 1 surveys. The decrease was across the study area and included the areas of recent and current EBSP activities, EBSP areas where construction is yet to begin, and the shoreline reach of the Olympic Sculpture Park, north of the EBSP area.

5 Corridor Physical Characteristics

This section presents the methods and Year 1 results of the corridor physical characteristics cross-section surveys. Cross-section surveys were conducted to evaluate physical changes to habitat zones and the confined habitat benches. The Year 1 cross-section surveys were performed at two locations, the Aquarium north site and the Spring Street site, shown in Figures 11, 12, and 13, respectively.

5.1 Methods

Year 1 corridor physical characteristics cross-section surveys were performed by Anchor QEA on August 24 and September 18, 2018. The cross-section survey methods followed the methods identified in the monitoring plan (Tetra Tech 2013), with the following changes proposed in the monitoring plan update (SDOT 2017):

- Surveys at the HIZ were not performed in Year 1 because this site was under construction.
- Year 1 cross-section surveys were performed annually in Year 1 instead of monthly because the HIZ (formerly Zone 1 habitat beach) was not yet constructed and limited change is anticipated on the confined habitat benches.

At the Aquarium north site, where the expanded bench was constructed in October and November of 2016, survey elevations were collected along three alignments (Figures 11 and 12). At the Spring Street site (Pier 54 and Pier 55), where marine mattresses were constructed to form a confined habitat bench, survey elevations were collected along one alignment (Figure 13).

The post-construction elevation survey was conducted using a survey rod and hand level. Elevation lines on the seawall provided backsight reference points to provide absolute elevations. For additional elevation data at the Aquarium north site, a drone survey was conducted at low tide and processed using photogrammetry software to create a digital surface model. Elevation data were collected in North American Vertical Datum 1988 (NAVD88) and converted to MLLW. A sieve evaluation was also performed during the cross-section surveys.

5.2 Results

5.2.1 Cross Section Surveys

For the Aquarium north site, surveyed elevations of the extended habitat bench were compared to the 2016 multi-beam hydrographic as-built survey of the extended habitat bench conducted by Pacific Pile and Marine/TerraSond Ltd (Table 5). As shown in the table, elevations were recorded in NAVD88 and MLLW datums. The variance from as-built column shows the difference between the Year 1 elevations and the as-built elevations. At this site, on average, the post-construction survey elevations were 0.45-feet lower than the 2016 as-built survey elevations. This amount of settlement

and potential erosion falls within the normal range for the amount, size, and type of material placed when considering this site's location, configuration, and existing substrate conditions.

Table 5
Aquarium North Site Cross-Section Survey Data

Point #	Distance from Seawall Face (feet)	Year 1 MLLW Elevation (feet)	Year 1 NAVD88 Elevation (feet)	As-Built NAVD88 Elevation (feet)	Variance from As-Built (feet)
A-A'					
1	2.5	-0.66	-3.00	-2.70	-0.30
2	10	-0.96	-3.30	-2.90	-0.40
3	20	-1.06	-3.40	-2.80	-0.60
4	30	-1.06	-3.40	-3.10	-0.30
5	40	-1.26	-3.60	-3.30	-0.30
6	50	-1.26	-3.60	-3.30	-0.30
7	55	-0.66	-3.00	-3.00	0.00
8	60	-0.26	-2.60	-1.84	-0.76
9	65	-0.56	-2.90	-2.59	-0.31
10	75	-2.66	-5.00	-4.50	-0.50
				Average	**-0.38**
B-B'					
1	18	-0.96	-3.30	-2.90	-0.40
2	28	-1.26	-3.60	-3.20	-0.40
3	38	-1.56	-3.90	-3.30	-0.60
4	48	-0.86	-3.20	-2.00	-1.20
5	53	-0.06	-2.40	-1.80	-0.60
6	58	-0.26	-2.60	-2.30	-0.30
7	63	-1.66	-4.00	-3.30	-0.70
				Average	**-0.60**
C-C'					
1	18	-0.56	-2.90	-2.80	-0.10
2	26	-1.16	-3.50	-3.10	-0.40
3	36	-1.06	-3.40	-2.70	-0.70
4	41	-0.56	-2.90	-2.40	-0.50
5	46	-0.96	-3.30	-3.20	-0.10
				Average	**-0.36**
				Average of three sections	**-0.45**

For the Spring Street site, marine mattresses were placed according to the design, so elevations were compared to the 2013 central seawall design elevations provided by Parsons (Table 6). As shown in the table, elevations were recorded in NAVD88 and MLLW datums. The variance from as-built column shows the difference between the Year 1 elevations and the as-built elevations. At this site, on average, the post-construction survey elevations were 0.26-feet lower than the 2013 design elevations. This amount of settlement and potential erosion falls within the normal range for the amount, size, and type of material placed when considering this site's location, configuration, and existing substrate conditions.

Table 6
Spring Street Site Cross-Section Survey Data

Point #	Distance from Seawall Face (feet)	Year 1 MLLW Elevation (feet)	Year 1 NAVD88 Elevation (feet)	As-Built NAVD88 Elevation (feet)	Variance from Design (feet)
D-D'					
1	0	-5.04	-2.70	-2.64	-0.06
2	3	-5.24	-2.90	-2.77	-0.13
3	6	-5.74	-3.40	-2.93	-0.47
4	9	-5.84	-3.50	-3.22	-0.28
5	12	-5.94	-3.60	-3.24	-0.36
				Average	**-0.26**

5.2.2 Sieve Evaluation

At the Aquarium north site, a material called Modified Loose Substrate was placed during construction. According to the construction specifications and field verification during construction, Modified Loose Substrate generally consisted of 0.5- to 3-inch sub-angular to angular gravel. Measurements taken during this Year 1 survey confirmed consistent sizing and shape.

At the Spring Street site, quarry spalls wrapped in high strength geogrid marine mattresses were placed during construction. According to the construction specifications and field verification during construction, the marine mattress quarry spalls generally consisted of 0.5- to 6-inch angular gravel with an average diameter of 3 to 4 inches. Measurements taken during this Year 1 survey confirmed consistent sizing and shape.

6 Epibenthic, Illumination, and Fish Surveys

Three Year 1 EBSP survey tasks were performed as identified in the monitoring plan (Tetra Tech 2013) and the monitoring plan update (SDOT 2017). EBSP survey tasks included:

- Invertebrate colonization of benches (habitat beach construction not completed)
- Illumination
- Salmon presence and behavior

The following sections present the methods, results, figures, and photographs for these three EBSP tasks incorporated from the *University of Washington 2018 Seawall Data Report* (University of Washington 2018). Data result tables and additional survey photographs from the University of Washington Data Report are included in Appendix B.

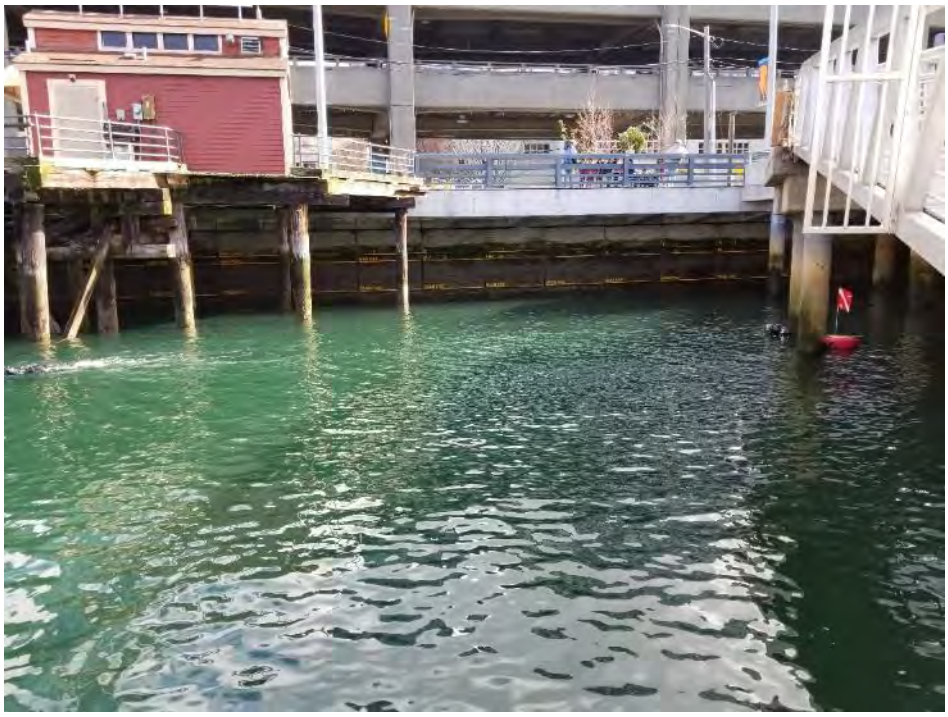
6.1 Introduction

The 2018 data report summarizes the post-construction monitoring of epibenthic invertebrates, light levels, and fish within the completed EBSP area and appropriate reference areas. These data, when combined with monitoring to be conducted in 2019, will allow for evaluation of the effectiveness of habitat enhancements associated with the new seawall—addition of texture and relief to the wall, construction of shallow water benches, and addition of light penetrating surfaces to the sidewalk. Findings in the data report should be considered as preliminary, and a full monitoring report with statistical analysis and interpretation will be completed in January 2020 after both years of monitoring.

6.1.1 Project Goals

Post-construction biological sampling was conducted from March to October 2018, a period coinciding with presence of juvenile salmon near shore. Sampling was planned to initiate in February 2018, but, due to storms in February that prevented safe field sampling, the sampling effort was shifted to early March. Sampling occurred in areas extensively sampled before seawall construction (Munsch et al. 2014; Cordell et al. 2017a,b), and that were enhanced during the Phase 1 rebuild. All sampling occurred at four sites (Figure 14). Site 1, labeled as Spring Street North and South, includes both under and between Piers 54 and 55 (Figure 15). Sites 2 and 3 are Pier 56 (University Street) and the Aquarium, respectively. Site 4 reference sampling occurred at the Olympic Sculpture Park (Figure 1). The seawall between piers did not have pier structure overhead, with exception of the section adjacent to Pier 55 (Spring Street North), which had some shading provided by an overhead deck associated with a food stand (Photograph 9).

Photograph 9
Pier 55 (Spring Street North) Seawall on the Left, Showing Shading by an Overhead Deck Associated with the Frankfurter Food Stand; Pier 54 (Spring Street South) is on the Right



Research questions addressed in this study were:

1. How do assemblages and densities of small epibenthic invertebrates (e.g., amphipods, copepods) under LPS compare under piers versus in open areas? In addition to the summary of the 2018 epibenthic fieldwork included in this report (Section 6.2.1), samples are currently being processed in the laboratory, and the resulting data will be included in a separate report in April 2019.
2. How does the addition of LPS affect penetration of photosynthetically active radiation (PAR)? (Sections 6.2.2 and 6.3.1 and Appendix B).
3. How does the addition of LPS affect use of seawall habitats by juvenile salmon and other fish? (Sections 6.2.3 and 6.3.2 and Appendix B).

6.2 Methods

The epibenthic invertebrates, illumination, and fish survey monitoring methods followed the methods identified in the monitoring plan (Tetra Tech 2013), with the following changes proposed in the monitoring plan update (SDOT 2017):

- Epibenthic invertebrates monitoring was performed monthly April through July rather than monthly March through August because the modified months align better with the outmigration and productivity window.
- The epibenthic invertebrates behind Pier 55 and Aquarium North sites were replaced by the Pier 54, 55, 57 and Aquarium North sites because they provide better coverage of the completed work and to allow statistical analysis.
- Epibenthic invertebrates monitoring at the Pier 62/63 site was not sampled during Year 1 because construction was ongoing during 2018 at this location.
- Epibenthic invertebrates monitoring at the Zone 1 habitat beach site was not sampled during Year 1 because the Zone 1 habitat beach is not yet constructed.
- Illumination monitoring was performed monthly April through July rather than monthly February through October because the modified months align better with the outmigration and productivity window.
- Illumination equipment included portable light sensors only instead of continuous and portable light sensors because continuous Illumination loggers have been unreliable.
- The Spring Street and behind Pier 55 illumination monitoring sites were replaced by the Pier 54, 55, and 57 sites because they provide better coverage of the completed work and to allow statistical analysis.
- Illumination monitoring at the Seattle Aquarium and Pier 62/63 sites were not sampled during Year 1 because construction was ongoing during 2018 at these locations.
- Illumination monitoring at the Vine Street and Pier 69 sites were not performed because seawall work is not yet funded for design or construction in this north area of the seawall.
- The expanded bench, under Colman Dock, and Olympic Sculpture Park illumination monitoring reference sites were replaced with Olympic Sculpture Park and under pier along north seawall because construction is ongoing at Colman Dock, and the Olympic Sculpture Park provides a much better reference than the expanded beach location.
- The fish survey sites at Spring Street, Aquarium North, Vine Street, Olympic Sculpture Park, and Myrtle Edwards Beach were replaced by the Pier 54, 55, 57 and Aquarium North sites and Reference site at Olympic Sculpture Park only because they provide better coverage of the completed work and to allow statistical analysis.
- Fish survey monitoring was conducted during two daytime monitoring events per month via snorkel and one daytime SCUBA effort per month instead of two daytime and one nighttime monitoring event per month via snorkel, one daytime SCUBA effort per month, and two

daytime land-based monitoring per month. These changes were made because there were safety concerns with nighttime snorkeling, nighttime snorkeling is not effective (few if any fish are seen), and land-based monitoring has been determined to be unreliable.

6.2.1 Epibenthic Invertebrates

Epibenthic invertebrates were sampled once per month from April to July 2018 when juvenile salmon were abundant along the seawall, using a standard epibenthic invertebrate suction pump that has been used at the Olympic Sculpture Park (Toft et al. 2013) and for previous seawall studies (Cordell et al. 2017a). Detailed methods can be found at the Shoreline Monitoring Toolbox.[1] At each sampling location, five replicate pump samples were taken on the lower seawall and on the habitat bench. At the Aquarium, an additional transect was added on the extended bench in May to July (Photograph 10). At the Olympic Sculpture Park, a previously constructed and monitored habitat bench (Toft et al. 2013) was sampled to compare to the bench at the seawall enhancements.

Photograph 10
Epibenthic Pump Sampling of Invertebrates at University Street

[1] The Shoreline Monitoring Toolbox can be accessed at https://sites.google.com/a/uw.edu/toolbox/protocols/epibenthic-invertebrates.

6.2.2 Illumination

Light measurements of PAR were taken with a Li-Cor spherical underwater quantum sensor data logger during peak juvenile salmon outmigration between April and July 2018. Each measurement recorded an average of 15 seconds of PAR. In April and May, extensive measurements were conducted at many sampling locations (a full sampling at all sites could not be completed in April due to stormy weather, and so was extended into May). More focused light measurements were conducted from late-May through July, because the light changes that naturally occurred during the lengthy amount of sampling time (2 days per site) compromised data interpretation and precision and to take measurements in conjunction with high-tide snorkel surveys providing PAR measurements overlapping with fish observations. This method change was discussed and confirmed with the City of Seattle and Anchor QEA staff in May.

6.2.2.1 Extensive Light Measurements (April to May)

Two transects were sampled parallel to the seawall: one under the cantilevered sidewalk with LPS and over the habitat bench and one in deeper water without enhancements. PAR measurements were taken every 5 meters, at the pier margin, and 1 meter on either side of the pier margin. Two transects were also sampled perpendicular to the seawall: one under the pier and one between piers, taking measurements every meter from the seawall edge to 10 meters away. At all locations, measurements were taken above the water surface (in air), 0.3 meter below the water surface, 1 meter below the water surface, and if water depth allowed, at 2 meters below the water surface. These were taken at higher tide levels when water was over the habitat bench. In-air measurements were also taken above the LPS from the sidewalk at the two perpendicular transect locations (center of LPS).

6.2.2.2 Focused Light Measurements (May to July Overlapping with Snorkel Surveys)

Focused light measurements focused on three locations: 1) under pier; 2) edge of pier; and 3) away from pier. At each location, measurements were taken as per the extensive measurements, at locations both under and away from the LPS, and at the various depths. These were taken at higher tides when there was enough water depth, immediately after high tide snorkel surveys.

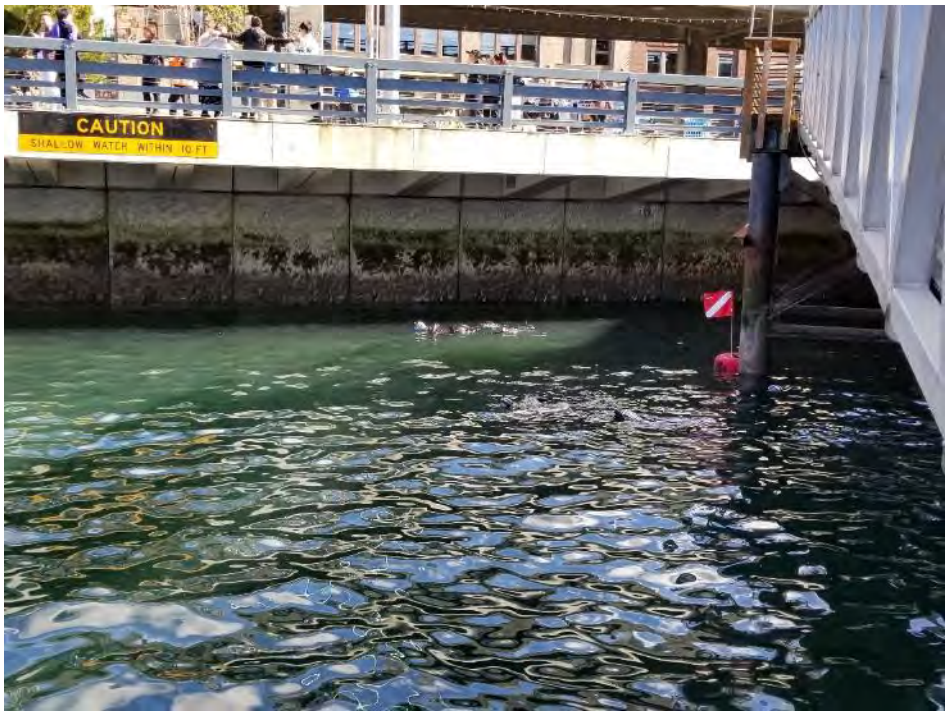
6.2.3 Fish Surveys

6.2.3.1 Snorkel

Snorkel surveys were conducted from March to October 2018 to collect data on fish abundance, size, distribution, and behavior patterns (Toft et al. 2007, 2013; Munsch et al. 2014). Each site was sampled twice per month March through July during the peak juvenile salmon outmigration (originally planned for once in February and March, but shifted to twice in March due to storms in February) and once per month in August through October. Transects were sampled at 3 meters and 10 meters from the seawall edge, corresponding to: 1) shallow water under the LPS and over the habitat bench;

and 2) deeper water away from the LPS. Each survey consisted of one snorkeler at each transect, snorkeling at the same time parallel to shore (Photograph 11). Transects were conducted at both high and low tide stages. Observations were standardized by transect length and visibility, allowing density estimates (number per square meter [#/m^2]). Location of the shade line of the piers, which varied with the sun angle, was recorded if present. Water temperature, salinity, weather, and horizontal secchi disk visibility were also recorded. Complete methods can be found at the Shoreline Monitoring Toolbox.[2]

Photograph 11
Snorkelers Surveying Shallow and Deep Water Transect Depths, Next to Pier 54 (Spring St. South)



Transects under piers were all 25 meters in length starting at the pier edge. Transects in between piers were also 25 meters at the University Street and Aquarium sites, and were split into 12.5-meter lengths at the Spring Street North and South piers due to the limited space available. At the Olympic Sculpture Park, the entire pocket beach was surveyed at 35 meters, and a 75-meter transect was surveyed at the habitat bench. At the pocket beach, an additional pair of transects was conducted at high tide to account for the shallow gradient at the beach that was not present at the seawall sites.

[2] The Shoreline Monitoring Toolbox can be accessed at https://sites.google.com/a/uw.edu/toolbox/protocols/fish.

Starting in May, an additional pair of transects was added to the extended bench at the Aquarium to account for the extra shallow water space.

6.2.3.2 SCUBA

SCUBA transects were conducted once per month April through July. Two paired divers surveyed transects parallel to shore at both shallow and deep depths, similar to snorkel surveys. Shallow depths were over the habitat bench, and deep depths were at the base of the sheet pile wall supporting the bench. Transect lengths were same as for snorkel surveys. Surveys were conducted at high tides when there was water over the bench. Observations were standardized by transect length and visibility, to estimate densities (#/m^2) of demersal fish and crabs. For each fish observation, habitat (e.g., sediment types) and algae (e.g., green) types were recorded when pertinent to the fish observation. Number of kelp stipes were counted along the entire transect (Photograph 12).

Photograph 12
Bull Kelp Around the Periphery of the Extended Bench at the Aquarium, June 2018

At the Aquarium site, numerous under-pier pilings precluded conducting a deep transect at the base of the sheet pile. Instead, this effort was shifted to surveying a 30-meter transect around the perimeter of the extended bench in between the piers.

On August 14, 2018, subtidal substrate enhancement placed off Waterfront Park was surveyed via SCUBA. The location of the enhancement was determined using SDOT survey maps. Data were

recorded consistent with previous SCUBA methods. Paired transects were conducted over the midpoint of the substrate enhancement (20-meter length), and over an adjacent non-enhanced reference area (12-meter length, as space allowed, ending at the pier edge). In addition to fish and crab observations, algae were identified and percent cover was quantified using a 0.5 meter per side quadrat. Algae observations occurred at uniform spacing along transects with seven replicates at the enhanced site and four replicates at the reference site, as space allowed.

6.3 Results

6.3.1 Illumination

Depending on the cloud cover and water depth, percent of ambient light in otherwise shaded conditions underneath LPS in piers ranged from 0.5% to 2.4% of ambient light (Appendix Tables B1 to B3). Despite these low PAR levels, they were 1.4 to 6.1 times higher than the light levels in the dark areas of piers without LPS. Note that light levels did not always steadily decrease with water depth, due to the angle of the sun interacting with pier and sidewalk, sometimes shading was greater at the surface of the water than the bottom of the water column.

6.3.2 Fish Surveys

6.3.2.1 Physical Data

Water quality data, salinity, and temperature collected during the fish surveys is presented in Appendix Tables B4 and B5.

6.3.2.2 Snorkel Surveys

Chum (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) and shiner perch (*Cymatogaster aggregata*) were the most abundant taxa along the seawall (Appendix Table B6). Juvenile salmon occurred mostly in April and May, while shiner perch occurred consistently from April through October. Other relatively abundant fish included striped seaperch (*Embiotoca lateralis*), tubesnout (*Aulorhynchus flavidus*), and herring (*Clupea harengus*).

With respect to position in the water column, juvenile salmon and forage fish had nearly equal distributions with ~64% of the individuals in the middle of the water column and 35% at the surface. Other fish groups were more in the middle to bottom of the water column (Appendix Table B7).

Overall densities for all fish and for juvenile salmon were highest at the seawall between the piers and Olympic Sculpture Park habitat bench sites (Figure 16), suggesting that relatively high numbers of fish can benefit from habitat enhancements at these habitats. Juvenile salmon densities underneath piers were lower, similar to pre-enhancement conditions, but were also similar to those

at the Olympic Sculpture Park pocket beach. Surfperch and forage fish were abundant at all strata except under piers, where the tubesnout were the only relatively abundant species.

At open seawall sites, juvenile salmon appeared to be affected by shading caused by the cantilevered sidewalk. At these sites, juvenile salmon were more abundant in the deep transects at high tide, appearing to avoid the darker areas under the sidewalk. The opposite occurred at low tides, when sunlight penetrated more under the cantilevered sidewalk and juvenile salmon densities were higher at the shallow transects.

Chum and pink salmon had the highest densities, with higher densities at the seawall and Olympic Sculpture Park habitat bench strata and lower densities at the under-pier and Olympic Sculpture Park beach strata (Figure 17). Seawall strata had the highest densities of categories containing Chinook salmon (*Oncorhynchus tshawytscha*), with these categories occurring more evenly across the other strata. Coho salmon (*O. kisutch*) densities were low.

Along the seawall during high tides, juvenile salmon were more abundant in the deep transect, which was not shaded by the cantilevered sidewalk, with lower densities under the LPS (Figures 18 and 19). The opposite occurred at low tides, when sunlight penetrated more under the cantilevered sidewalk, and juvenile salmon densities were higher at the shallow transect. Juvenile salmon were less abundant in under-pier habitats compared to open seawall habitats. However, for those salmon that did occur under piers during both high and low tides, densities were higher in shallow transects located under LPS with associated habitat benches, compared to deeper transects without LPS or habitat enhancements. This indicates that a proportion of the juvenile salmon along the seawall are using the corridor under the piers lit by LPS. This is in contrast to pre-construction results that showed very few juvenile salmon occurring under piers. Juvenile salmon densities were low during low tides at the Olympic Sculpture Park pocket beach, when there was not much water and therefore not much inhabitable space for fish. The Olympic Sculpture Park habitat bench had similar juvenile salmon densities at shallow and deep transects during high tides, and a similar pattern as found at the seawall strata during low tides, with higher juvenile salmon densities in shallow transects. Forage fish had the highest densities at deep transects during high tides at pier strata, at shallow transects during high tides at the Olympic Sculpture Park pocket beach, and at deep transects during low tides at the Olympic Sculpture Park habitat bench.

At the Aquarium extended bench, juvenile salmon densities were highest during high tides at the outer deep transect along the edge of the bench (Figure 20). They were also relatively high at the deep transect along the seawall at the edge of the cantilevered sidewalk. The only observations of trout across all sampling periods were at the Aquarium extended bench, where a total of eight trout were observed (six in June, two in August).

Results from SCUBA transects showed very few juvenile salmon or their potential predators in deeper waters off of the seawall. The most common fish observed were surf perches, tubesnouts, and larval fish. At the subtidal substrate enhancement near Waterfront Park, diversity was very low, with Pacific sanddabs (*Citharichthys sordidus*) and kelp crabs (*Pugettia producta*) recorded in the enhancement area but not in the reference area, and red rock crabs (*Cancer productus*) observed at both areas.

The percent of juvenile salmon feeding were similar across strata, ranging from 24% to 32% (Appendix Table B8). At the seawall and pier strata, more feeding occurred at shallow transects with habitat enhancements (33%), than at deep transects without habitat enhancements (20%). Among fish groups, juvenile salmon had the highest feeding percentage (27%) followed by forage fish (24%). For salmon, observations that included juvenile Chinook salmon had highest feeding percentages at the seawall and pier strata, and observations that included juvenile chum or pink salmon had highest feeding percentages at the seawall and lowest feeding percentages at the pier strata.

6.3.2.3 SCUBA Surveys

Water depth data collected during the scuba surveys are presented in Appendix Table B9. The most abundant fish observed on the SCUBA transects were larval fish in June and July (Appendix Table B10). As with the snorkel data, shiner perch were relatively abundant and occurred across sampling periods. Other relatively abundant taxa included tubesnouts in June and July and red rock crabs.

Most fish observed on SCUBA transects were not known predators of juvenile salmon (e.g., surf perches), were too small to feed on salmon (e.g., small lengths of observed sculpins), or did not co-occur with juvenile salmon, which were closer to shore or higher in the water column (see snorkel data; Appendix Table B11). Only one juvenile salmon was observed during SCUBA surveys near the bottom of the water column. One lingcod (*Ophiodon elongatus*) was observed at the bottom of the water column at the Olympic Sculpture Park pocket beach.

Surfperches were relatively abundant at seawall sites and the Olympic Sculpture Park pocket beach, in both shallow and deep transects, but were rare in under pier habitats (Figure 21). Tubesnout densities were similarly low in under pier habitats and otherwise were relatively abundant in deep transects. Larval fish were the only fish taxa abundant in under pier deep habitats transects, where they were patchy in distribution, but occurred in large schools. Larval fish also occurred at the deep seawall and shallow pocket beach transects. Divers noted that larval fish in deep SCUBA transects had demersal fish morphologies (e.g., sculpins) while those in shallow snorkel transects had more elongated forage fish morphologies (e.g., surf smelt). Under pier fish densities along the shallow transects were very low. Demersal fish that could be considered predators on juvenile salmon (e.g., lingcod, larger sculpin, larger rockfish) were extremely rare. Rockfish were most abundant at the Olympic Sculpture Park pocket beach in deep transects (all black rockfish [*Sebastes melanops*]) and were rare at the other sites.

Bull kelp was observed at three transects. The deep transect at the Aquarium seawall along the outer edge of the extended bench had the highest densities of bull kelp (average of 47.9 kelp stipes/100m^2), with lower densities at the deep transect at the Olympic Sculpture Park pocket beach (average of 0.8/100m^2) and the deep transect at the Spring Street south seawall (average 0.3/100m^2).

At the subtidal substrate enhancement near Waterfront Park, Pacific sanddabs and kelp crabs occurred in the enhancement area but not in the reference area, while red rock crabs were observed at both areas (Appendix Table B12). The brown algae *Saccharina latissima* was the most abundant alga at both sites. The remaining taxa were all red algae, with three taxa being unique to the enhanced habitat and two taxa unique to the reference habitat.

7 Conclusions

This section presents a summary of the conclusions from the Year 1 monitoring results discussed in Section 2 through 6 of this Report. The following section describes the EBSP nearshore habitat enhancement objectives and restoration targets.

7.1 EBSP Enhancement Objectives and Restoration Targets

The EBSP nearshore habitat enhancement objectives identified in the monitoring plan (Tetra Tech 2013) include the following:

- Create an effective intertidal migratory corridor for juvenile salmonids
- Enhance the marine nearshore ecosystem quality and function

Table 7 presents the EBSP monitoring plan restoration targets, followed by a summary of results. As described in Table 7, several construction elements are not complete or have not yet begun and most restoration target schedules occur during future monitoring years. The findings in this Year 1 Report should be considered preliminary. Monitoring reports with statistical analysis and interpretation will be completed during future years of monitoring.

Table 7
Elliott Bay Seawall Project Nearshore Habitat Enhancement Objectives and Restoration Targets

Restoration Target	Schedule	Status
Objective 1: Create an effective intertidal migratory corridor for juvenile salmonids		
Increase illumination behind piers and below cantilevered sidewalks to increase light levels within the proposed intertidal corridor and diminish light/dark transitions as compared to existing conditions.	Immediately after replacement of the sidewalk and installation of LPS	Phase 1 construction elements completed; light levels ranged from 1.4 to 6.1 times higher than piers without LPS.
Create a continuous intertidal corridor at appropriate depth (~0 feet MLLW) for juvenile salmon migration along the entire length of the project.	Immediately after construction	Phase 1 construction elements completed; overall densities for all fish including juvenile salmon were highest at seawall and Olympic Sculpture Park habitat bench sites suggesting that relatively high numbers of fish can benefit from habitat enhancements at these habitats.
Achieve colonization of the loose substrate habitat benches and Zone 1 bench/beach by salmonid prey species.	Within 5 years after construction	In progress in Year 1; Zone 1 currently under construction.

Restoration Target	Schedule	Status
Observe statistical increase in presence of juvenile salmonids within the intertidal migratory corridor.	Within 3 years after construction	In progress in Year 1; statistical analysis pending, initial indications are a proportion of the juvenile salmon along the seawall are using the corridor under the piers lit by LPS.
Objective 2: Enhance the marine nearshore ecosystem quality and function		
Increase invertebrate and algal density and diversity on shelves/textured wall vs. flat seawall.	Statistically comparable to Goff (2010) results from panel experiments with stable density/diversity by Year 5 after construction	In progress in Year 1; the textured seawall is providing suitable attachment locations for multiple invertebrate and algal species.
Provide sufficient illumination to allow macroalgae to grow underneath cantilevered sidewalk and behind piers and also increase invertebrate diversity/density as compared with shaded under-pier locations.	Achieve 30% increased density/diversity under the cantilevered sidewalk by Year 5 and 15% increased density/diversity behind the piers as compared to a control shaded pier site	In progress in Year 1; a variety of macroalgae species were observed in uncovered areas and fewer species were observed in areas behind piers.
Provide suitable substrate for crab and other invertebrate colonization on the substrate enhancement sites as compared with adjacent silt/shell hash substrate.	Within 3 years of construction	In progress in Year 1; the substrate enhancement sites are providing suitable habitat for crab and other invertebrate species.
Provide sustainable riparian zone on upper area of Zone 1 beach/bench.	Within 3 years of construction achieve and maintain 80% cover of native tree, shrub, and herbaceous species	Zone 1 currently under construction.
Provide increased terrestrial insect input in areas of riparian vegetation as compared to areas without riparian vegetation.	Achieve minimum 10% increase at vegetated sites within 5 years compared to unvegetated sites	Zone 1 currently under construction; Phase 2 currently not funded.
Increase kelp distribution and density by 10 percent (averaged across entire survey area) as compared to pre-construction conditions.	Within 3 years of construction	In progress in Year 1; bull kelp presence and density were lower throughout study area (including reference site) than what was documented in the 2010 survey.

7.2 Invertebrate and Algal Attachment on Seawall

Twenty total invertebrate and algal species or families of species were observed at the Aquarium north and Pier 55 sites. At the uncovered sites, acorn barnacle was the most common species observed during the April, June, and August surveys. Additional common species included thatched barnacle, mussels, limpets, black tar, sea lettuce, and green string lettuce. Species diversity and density increased from the April to August surveys.

At the covered sites, acorn barnacle was also the most common species observed with other common species including crenulated barnacle, little brown barnacle, thatched barnacle, bryozoan, and biofilm. Species diversity and density increased from the April to August surveys. The uncovered sites showed higher species diversity and density than the covered sites. Algae species presence was much lower in the covered sites than the uncovered sites. The textured seawall is providing suitable attachment locations for multiple invertebrate and algal species in this first year of monitoring. However, even with LPS, areas under piers have reduced productivity. Additional years of monitoring will identify statistical differences between covered and uncovered areas and comparisons to control sites.

7.3 Macroalgae Growth Under the Light Penetrating Surfaces

Nine total macroalgae species or families of species were observed at the uncovered Aquarium north and Pier 55 sites. Sea lettuce was the most common species observed at the benches and at the Aquarium north site expanded bench.

Two species were observed at the covered areas of the Aquarium north and the Pier 55 sites. Unattached sea lettuce was observed at the Aquarium north site and red hair was observed at the Pier 55 site. No macroalgae was observed at the Aquarium north site expanded bench. A variety of macroalgae species were observed in this first year of monitoring. However, even with LPS, areas under piers have reduced productivity compared to uncovered areas. Additional years of monitoring will identify statistical differences between covered and uncovered areas and comparisons to control sites.

7.4 Bull Kelp Distribution and Density

Seven patches of 10 or more stipes were observed between Pier 70 and Pier 48 during the Year 1 survey compared to 14 during the 2010 survey. The largest patches were observed in the northern portion of the EBSP (i.e., north of Pier 66) and between the Aquarium and Pier 62/63.

Fewer patches were observed during the Year 1 survey compared to the 2010 survey results and there was an overall decrease in the number of bull kelp observed. The decrease was across the study area and included the areas of recent and current EBSP activities, EBSP areas where construction is yet to begin, and the shoreline reach of the Olympic Sculpture Park, north of the EBSP area. Additional years of monitoring will identify continued decline or an increase in bull kelp presence. A variety of recent and current research in Puget Sound has documented a decrease in bull kelp presence in recent years. Potential factors include temperature changes associated with climate change, sediment reducing light levels, shoreline alterations, toxic pollution, and consumption by predators.

7.5 Corridor Physical Characteristics

Year 1 results of the corridor physical characteristics cross-section surveys and sieve evaluation indicate settlement and potential erosion within the normal range for the amount, size, and type of material placed when considering each site's location, configuration, and existing substrate

conditions. As stated in the Post-Construction Monitoring and Adaptive Management Plan, "If the evaluation of cross-sections on the benches and/or beach shows 2 feet of erosion at any sampling location in less than 5 years (and the erosion was not specifically due to a 10-year storm or larger), the City and adaptive management agencies will evaluate if a change in material sizing or other measures such as reconfiguration of the bench (increasing the size of the 'lip' at the outer edge of the benches to retain more material) or beach is warranted." Results indicated 0.26 to 0.60 feet of settlement and potential erosion in Year 1, which is the year the majority of settlement/erosion is expected to occur. Additional corridor physical characteristic cross-section surveys and sieve evaluations will be conducted in Years 3, 5, and 10.

7.6 Epibenthic, Illumination, and Fish Surveys

Depending on the cloud cover and water depth, light in otherwise shaded conditions underneath LPS in piers ranged from 0.5% to 2.4% of ambient light. However, PAR levels were 1.4 to 6.1 times higher under piers with LPS than those under piers without LPS. This appeared to be enough light for juvenile salmon to feed normally because their feeding rates under piers with LPS were found to be similar to those in the other tested habitats. This observation is in contrast to previous studies showing little or no feeding under piers without LPS (Munsch et al. 2014). Also, at the seawall and pier strata, more feeding occurred at shallow transects with habitat enhancements than at deep transects without habitat enhancements.

Overall juvenile salmon and other fish densities were lowest in under-pier habitats and highest at open seawall sites and at the Olympic Sculpture Park habitat bench. However, a proportion of the juvenile salmon along the seawall did occupy the areas under the piers lit by LPS. This is in contrast to pre-construction results that showed very few juvenile salmon occurring under piers. When juvenile salmon did occur in under-pier transects, densities were higher in shallow transects located under LPS with associated habitat benches, compared to deeper transects without LPS or habitat enhancements. These results show that the combination of LPS and habitat enhancements under piers provides habitat functions for juvenile salmon that did not previously exist.

8 References

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Figures

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ANCHOR QEA

Figure 1
Vicinity Map
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

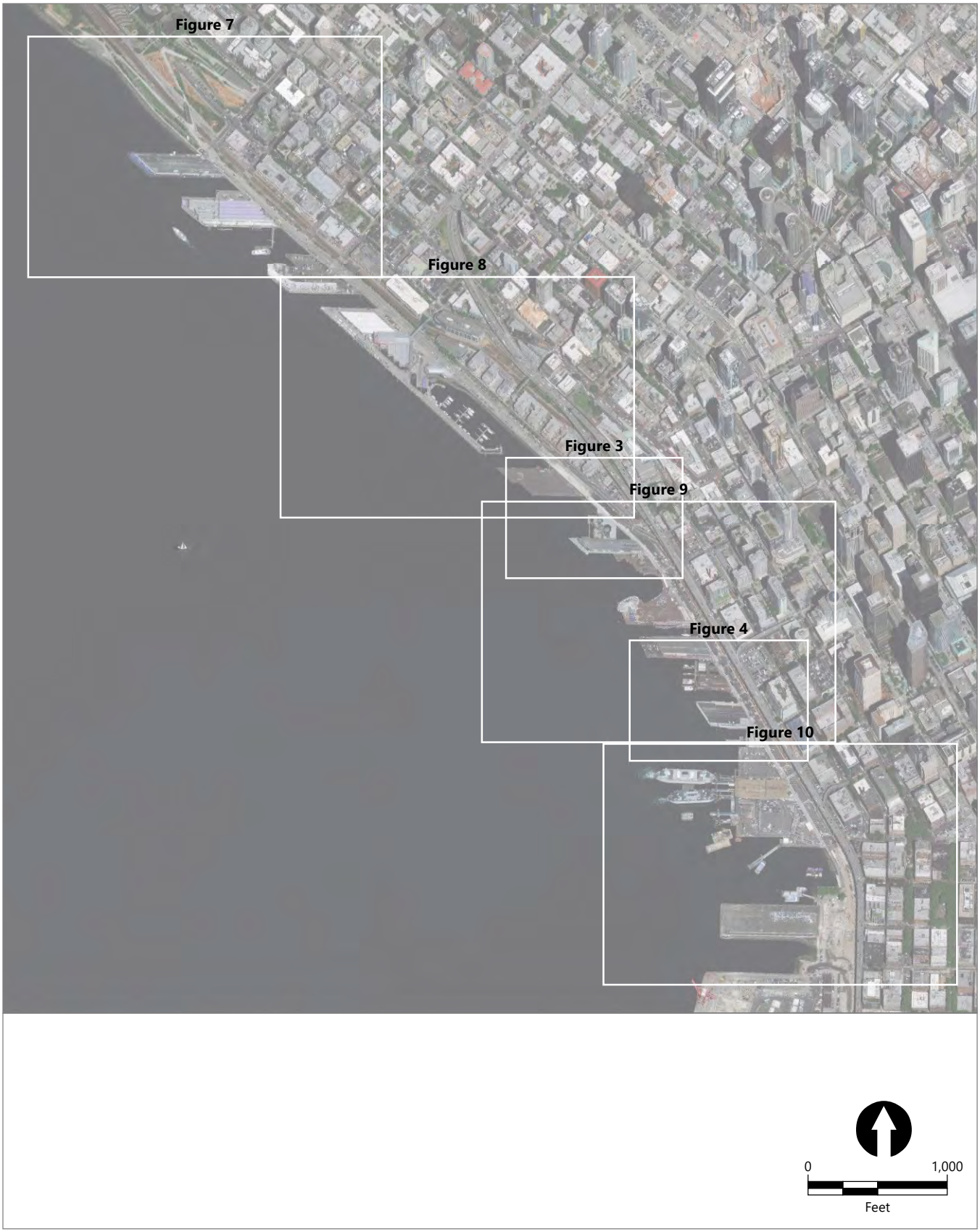

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Figure 2
Project Area
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

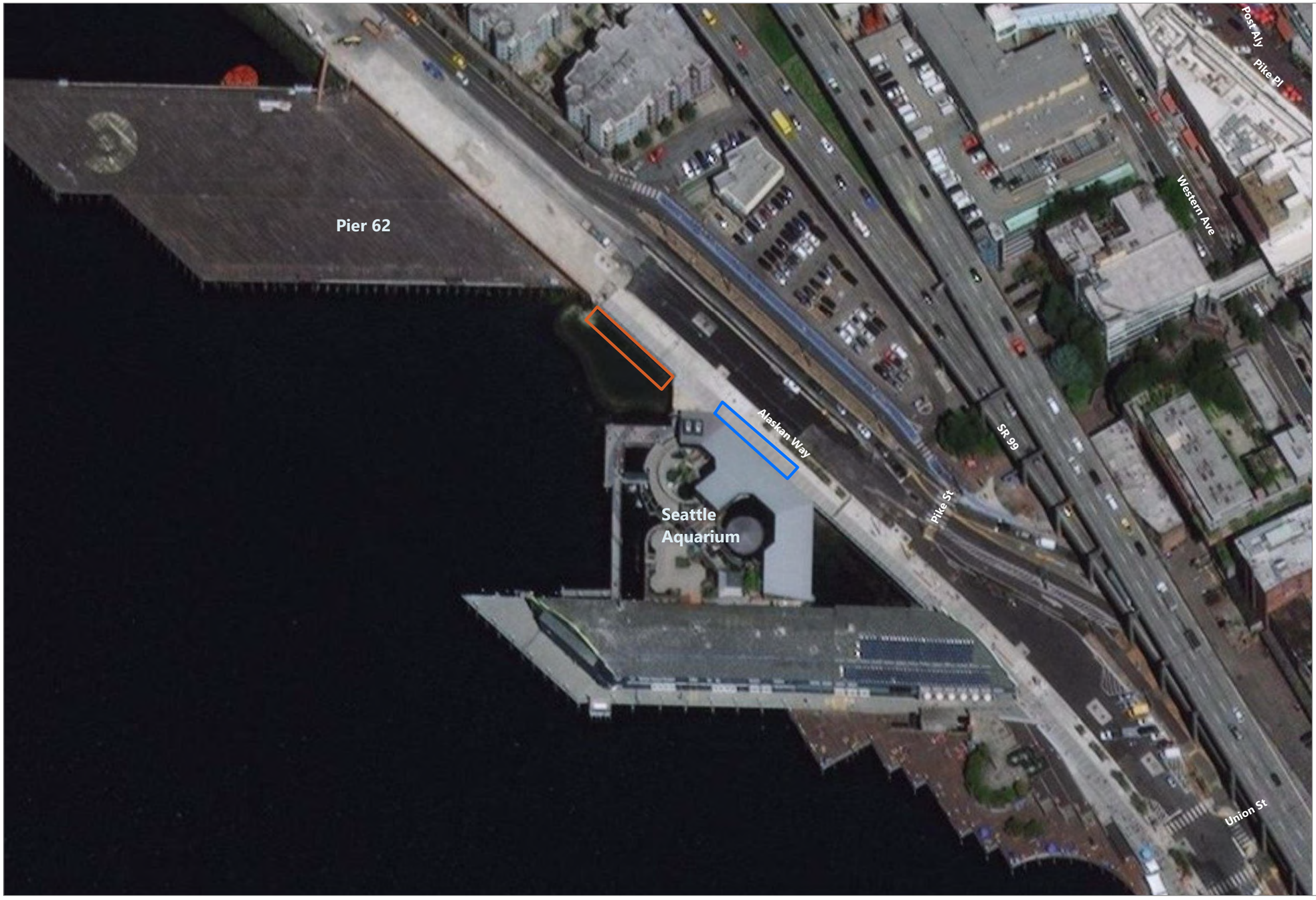

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Figure 3
Invertebrate and Algal and Macroalgae Aquarium North Monitoring Site
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

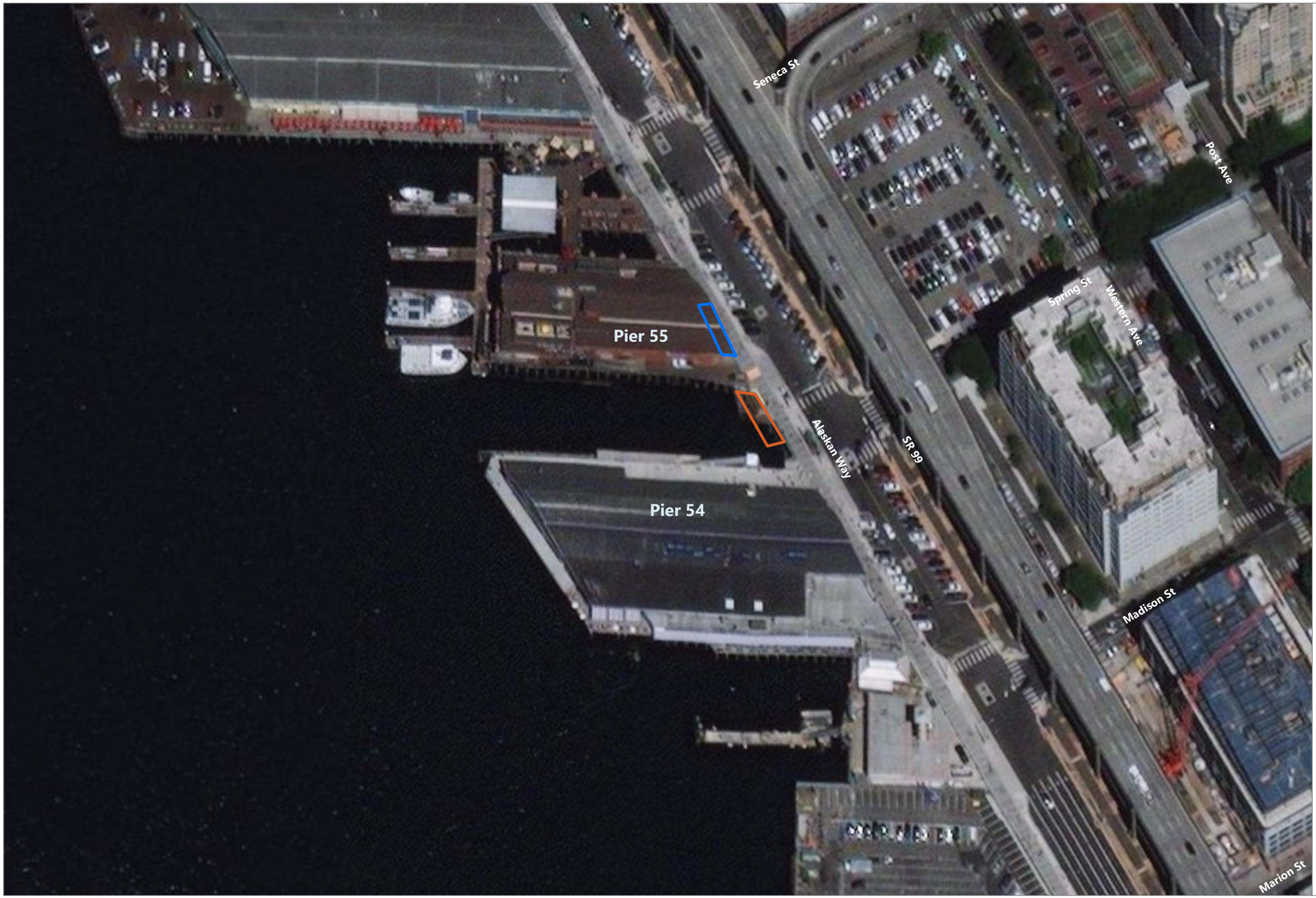

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Figure 4
Invertebrate and Algal and Macroalgae Pier 55 Monitoring Site
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

Figure 5
Average Percent Cover of Five Most Common Invertebrate and Algal Species

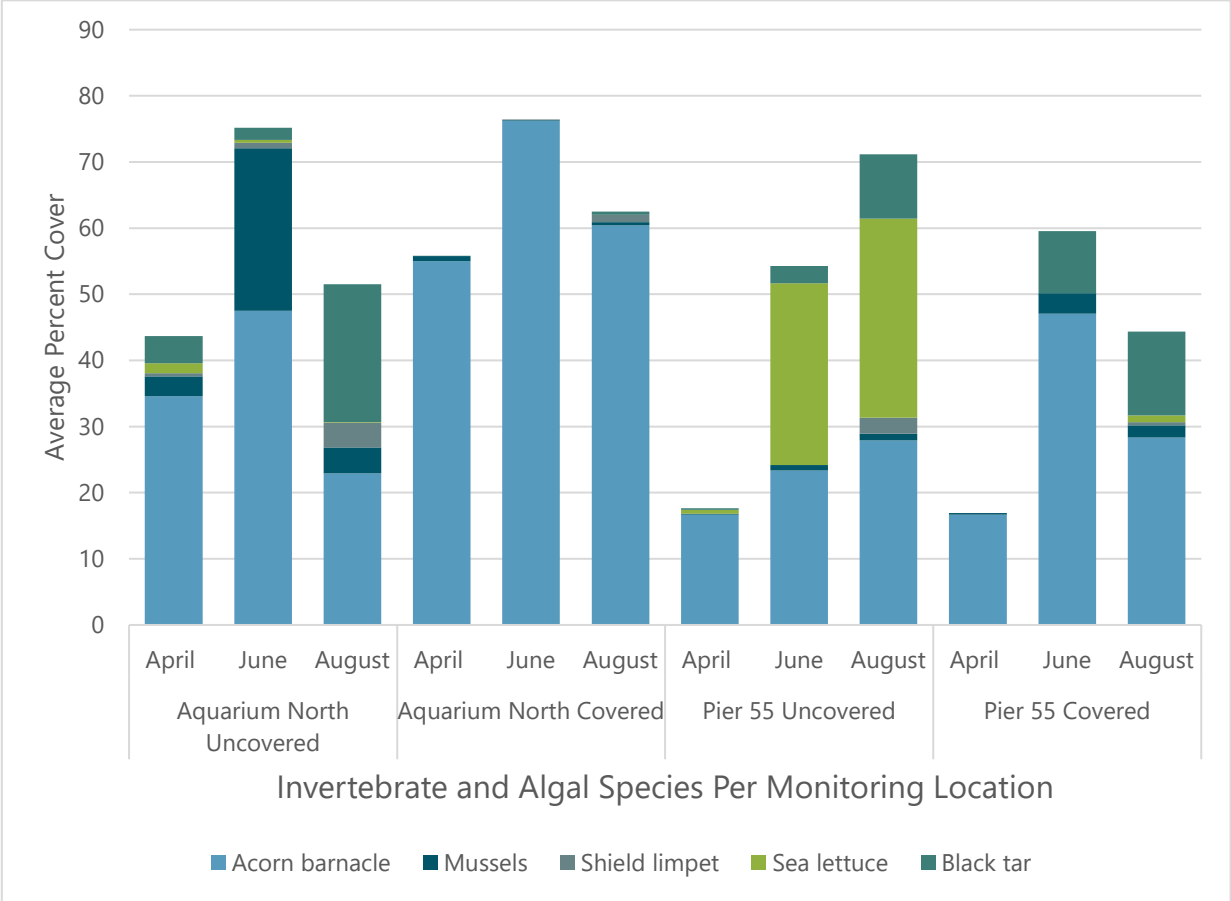
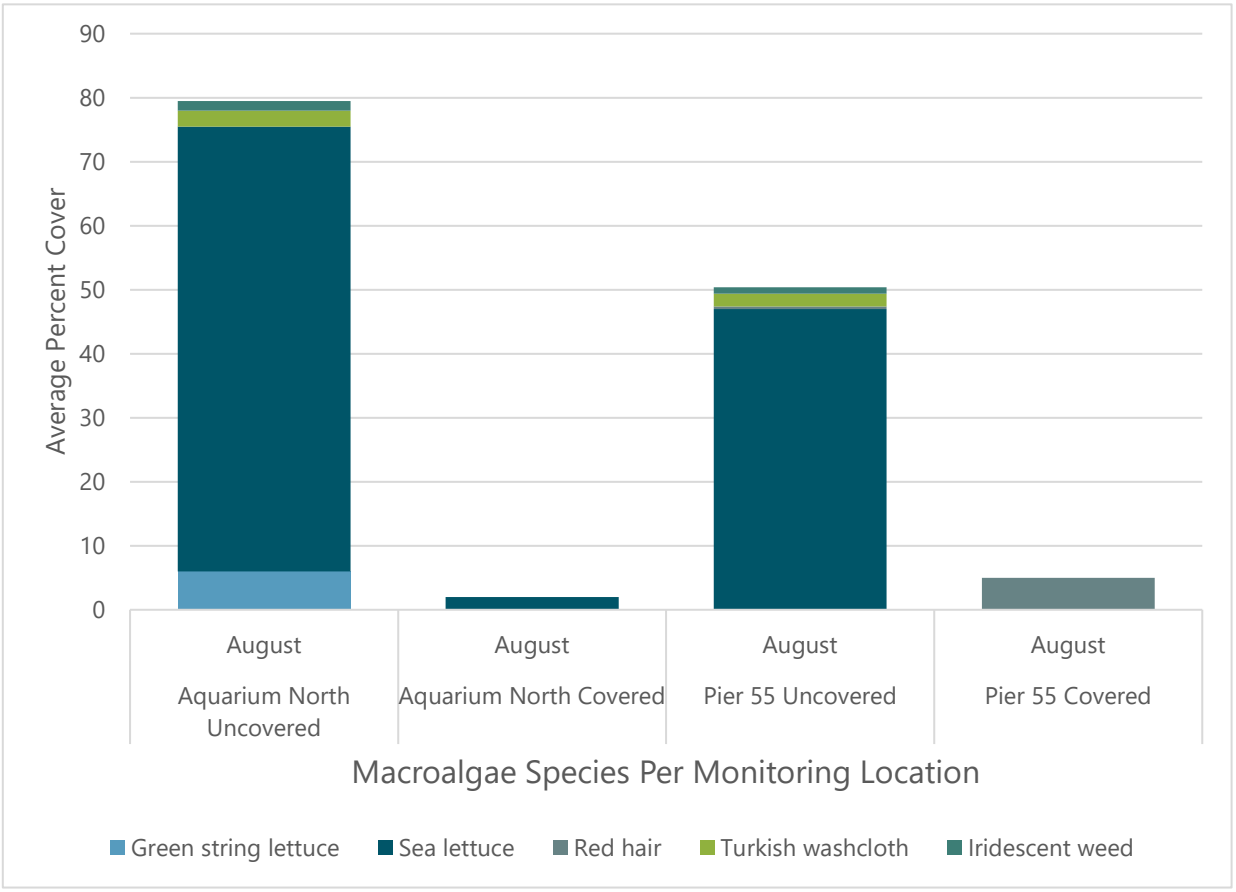


Figure 6
Average Percent Cover of Five Most Common Macroalgae Species



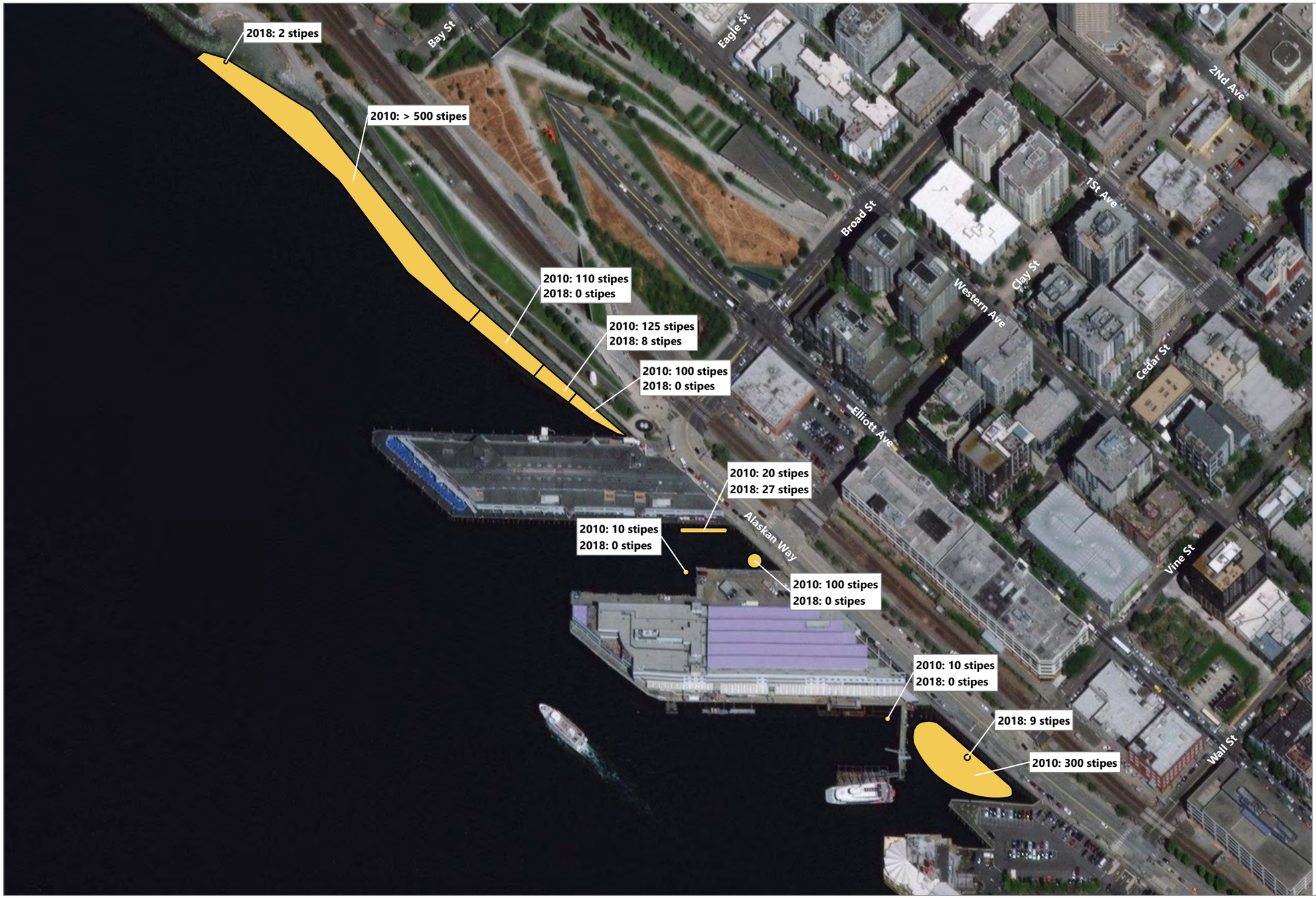


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Figure 7
2010 and Year 1 Bull Kelp Distribution Between Olympic Sculpture Park and Pier 67 (Edgewater Hotel)
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

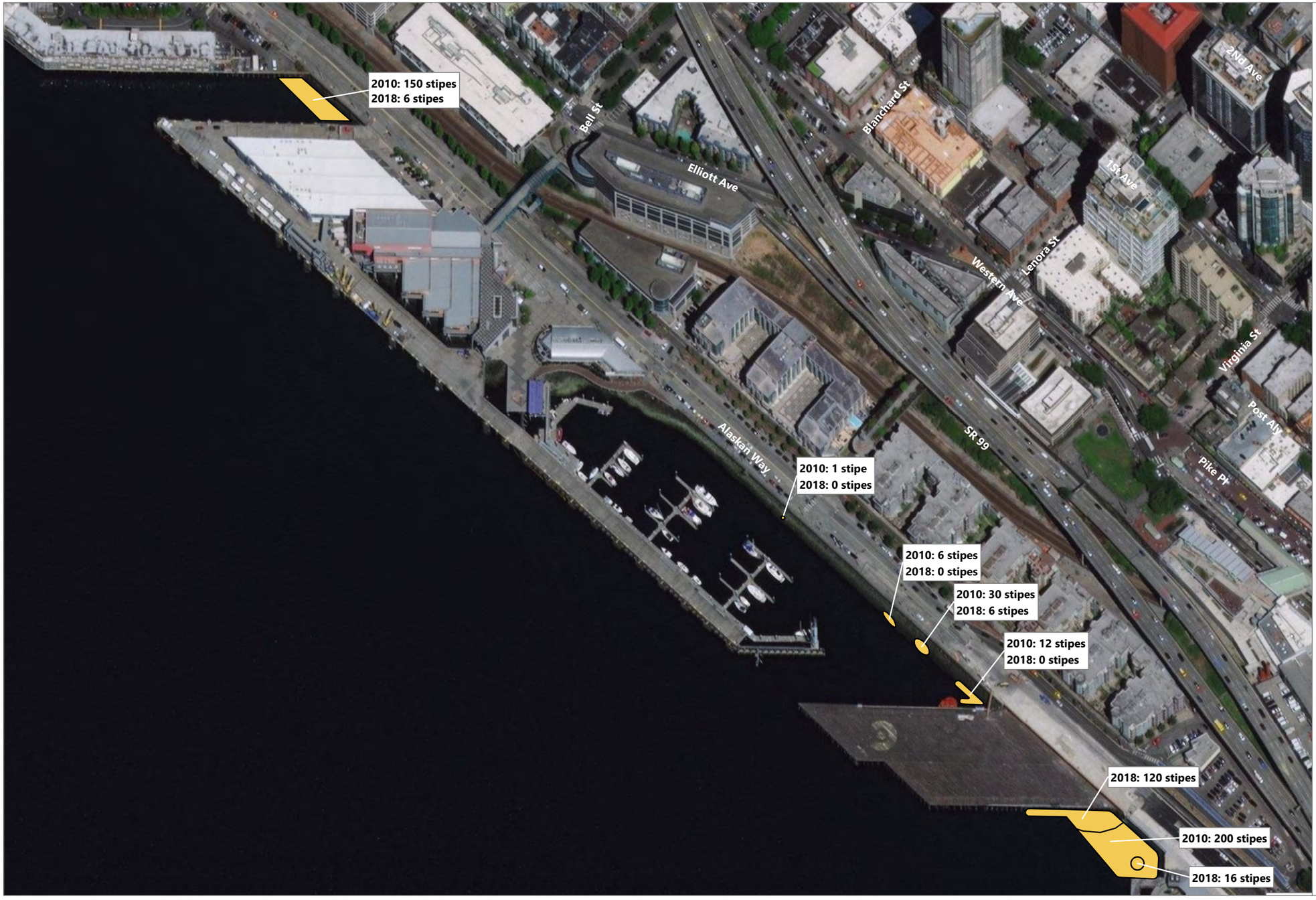

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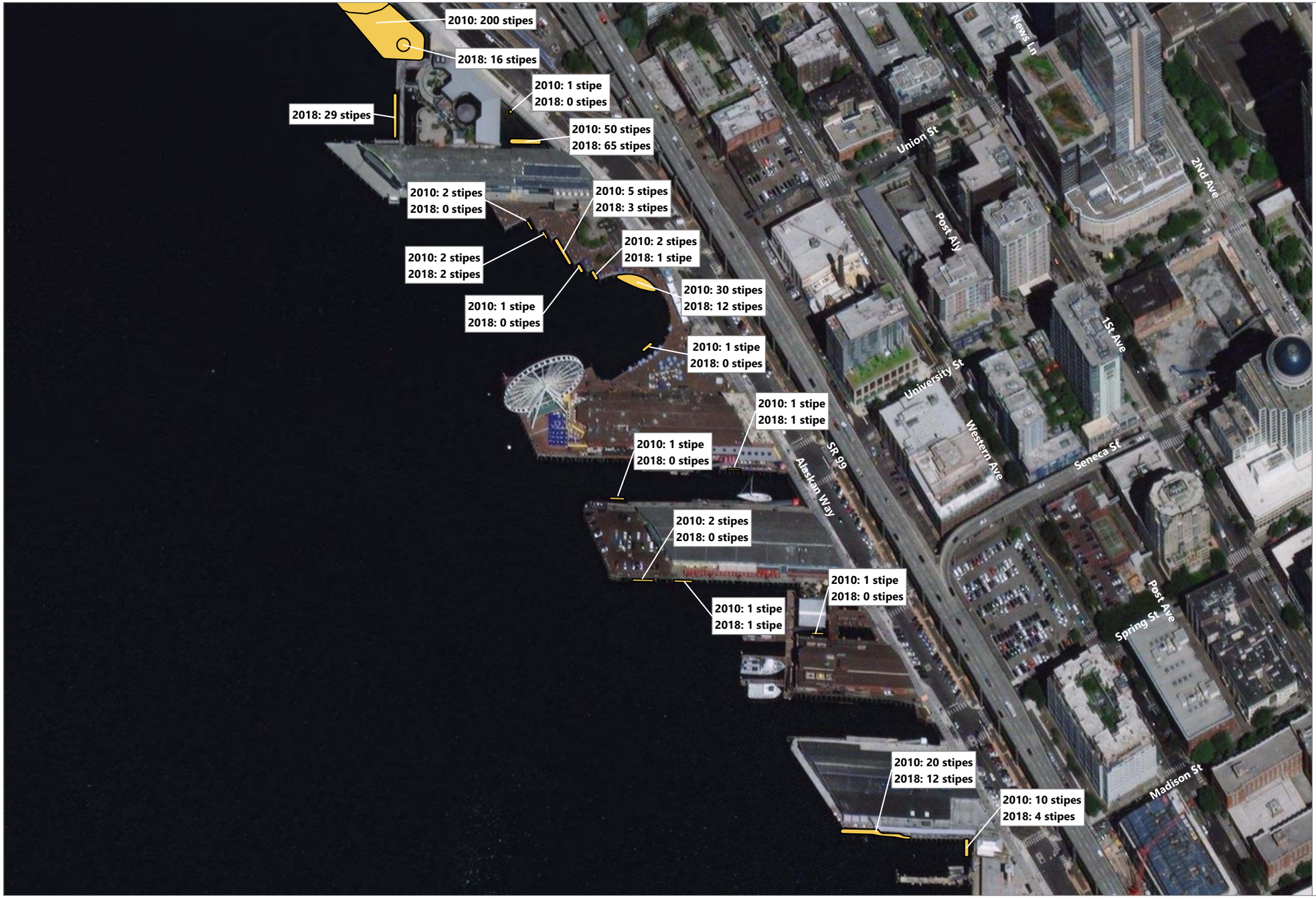
Figure 8
2010 and Year 1 Bull Kelp Distribution Between Pier 67 (Edgewater Hotel) and Pier 62/63
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project



LEGEND:

Bull Kelp Beds

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Feet

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Figure 9
2010 and Year 1 Bull Kelp Distribution Between Pier 62/63 and Pier 54
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

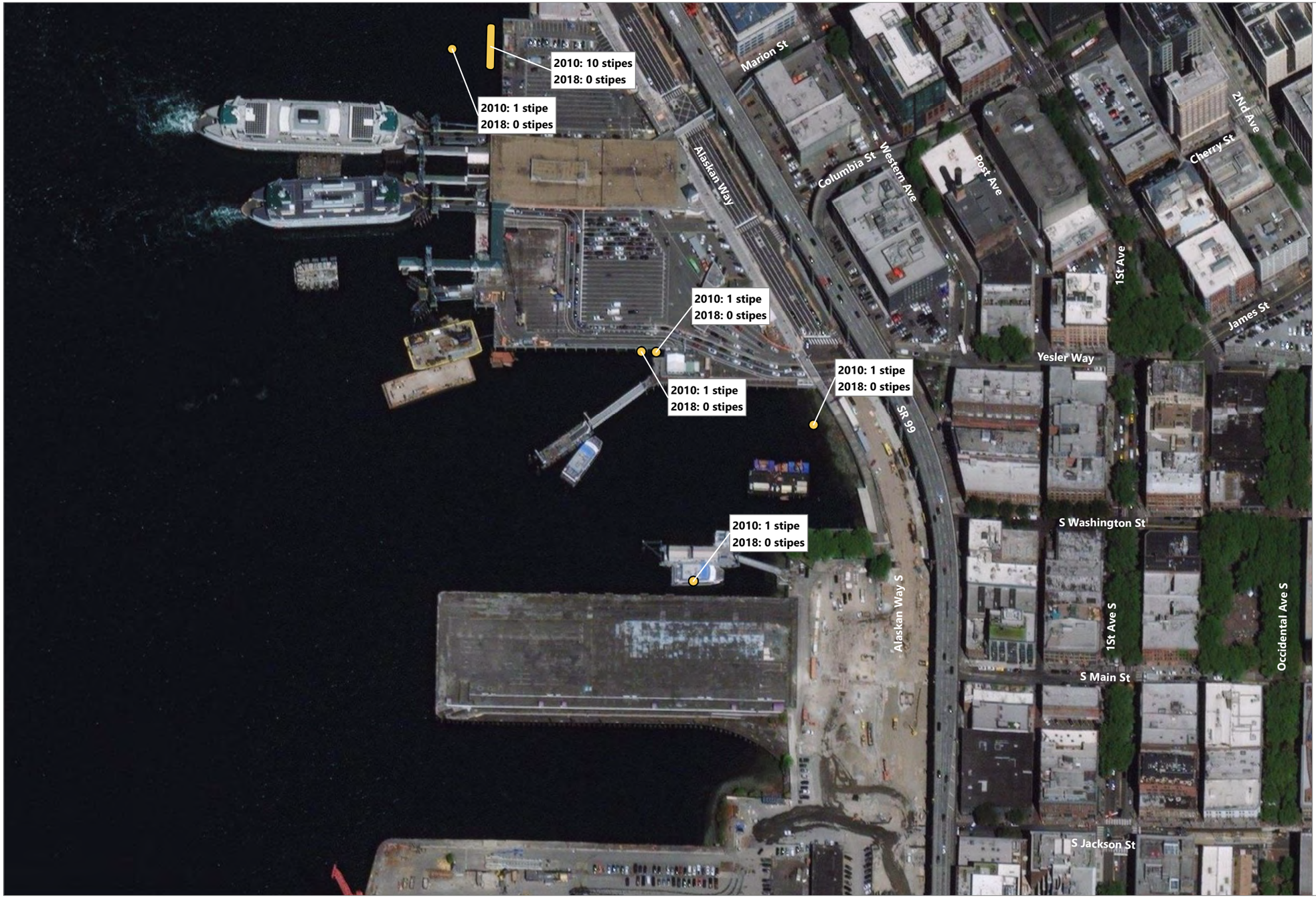

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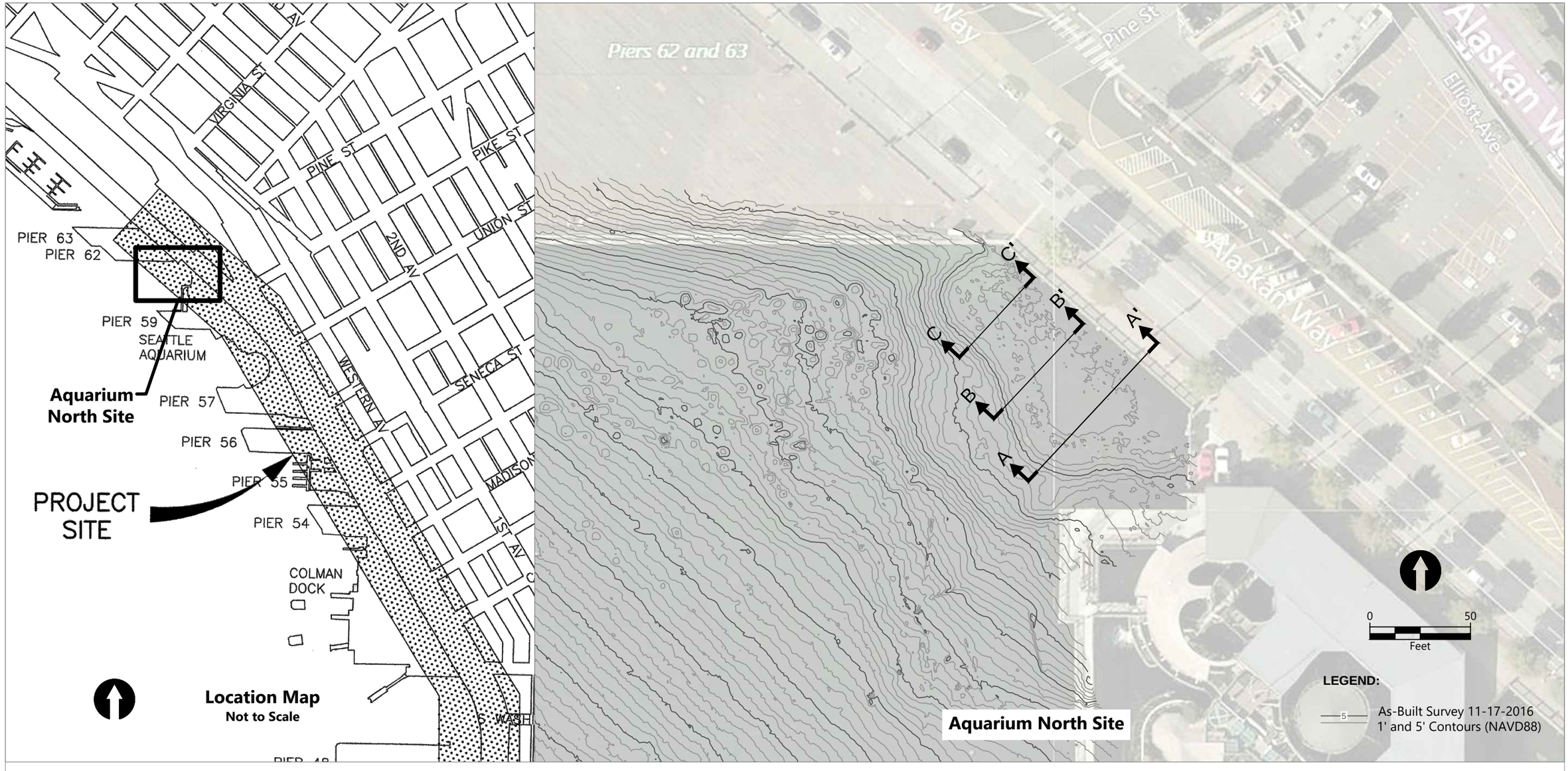
Figure 10
2010 and Year 1 Bull Kelp Distribution Between Pier 54 and Pier 47
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project



SOURCE: Drawing prepared from Central Seawall Design Drawings by Parsons dated September 2013, Pacific Pile and Marine/TerraSond Limited multi-beam hydrographic as-built survey conducted on 11-17-2016, Anchor QEA hand-held level post-construction survey conducted on 08-24-18, and Anchor QEA drone orthomosaic mapping survey conducted on 09-08-18.

HORIZONTAL DATUM: Local project datum, converted from NAD83/91, Washington State Plane North, NAD83, U.S. Feet.

VERTICAL DATUM: NAVD88 (GEOID 12A), U.S. Feet.

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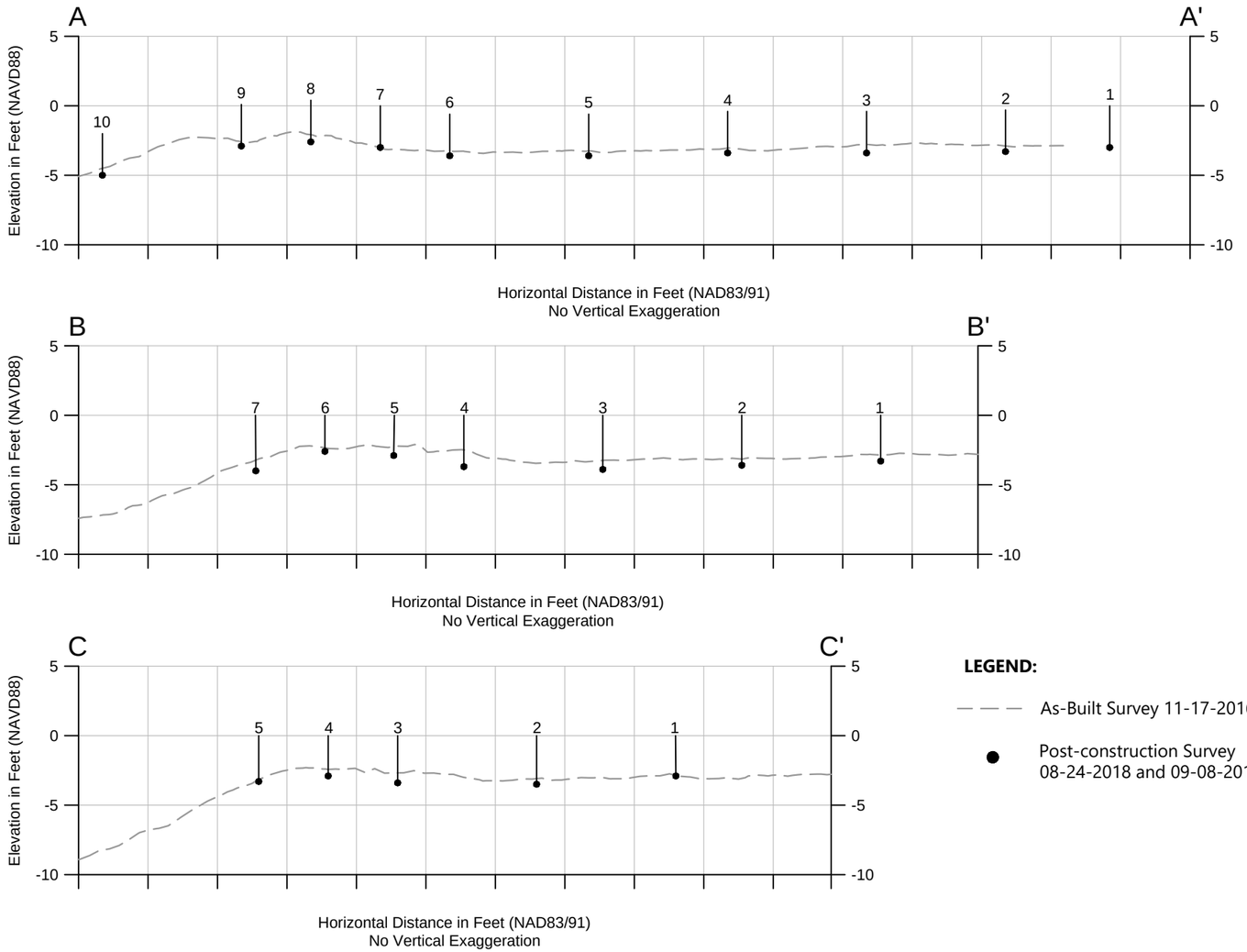
Figure 11
Year 1 Aquarium North Site Elevation Survey Plan View



LEGEND:

As-Built Survey 11-17-2016

Post-construction Survey
08-24-2018 and 09-08-2018

Survey Points Summary Tables:

A-A'

Point #	Distance from Seawall Face (ft)	NAVD88 Elevation (ft)	MLLW Elevation (ft)
1	2.5	-3.0	-0.66
2	10	-3.3	-0.96
3	20	-3.4	-1.06
4	30	-3.4	-1.06
5	40	-3.6	-1.26
6	50	-3.6	-1.26
7	55	-3.0	-0.66
8	60	-2.6	-0.26
9	65	-2.9	-0.56
10	75	-5.0	-2.66

B-B'

Point #	Distance from Seawall Face (ft)	NAVD88 Elevation (ft)	MLLW Elevation (ft)
1	18	-3.3	-0.96
2	28	-3.6	-1.26
3	38	-3.9	-1.56
4	48	-3.2	-0.86
5	53	-2.4	-0.06
6	58	-2.6	-0.26
7	63	-4.0	-1.66

C-C'

Point #	Distance from Seawall Face (ft)	NAVD88 Elevation (ft)	MLLW Elevation (ft)
1	18	-2.9	-0.56
2	26	-3.5	-1.16
3	36	-3.4	-1.06
4	41	-2.9	-0.56
5	46	-3.3	-0.96

SOURCE: Drawing prepared from Central Seawall Design Drawings by Parsons dated September 2013, Pacific Pile and Marine/TerraSond Limited multi-beam hydrographic as-built survey conducted on 11-17-2016, Anchor QEA hand-held level post-construction survey conducted on 08-24-18, and Anchor QEA drone orthomosaic mapping survey conducted on 09-08-18.

HORIZONTAL DATUM: Local project datum, converted from NAD83/91, Washington State Plane North, NAD83, U.S. Feet.

VERTICAL DATUM: NAVD88 (GEOID 12A), U.S. Feet.

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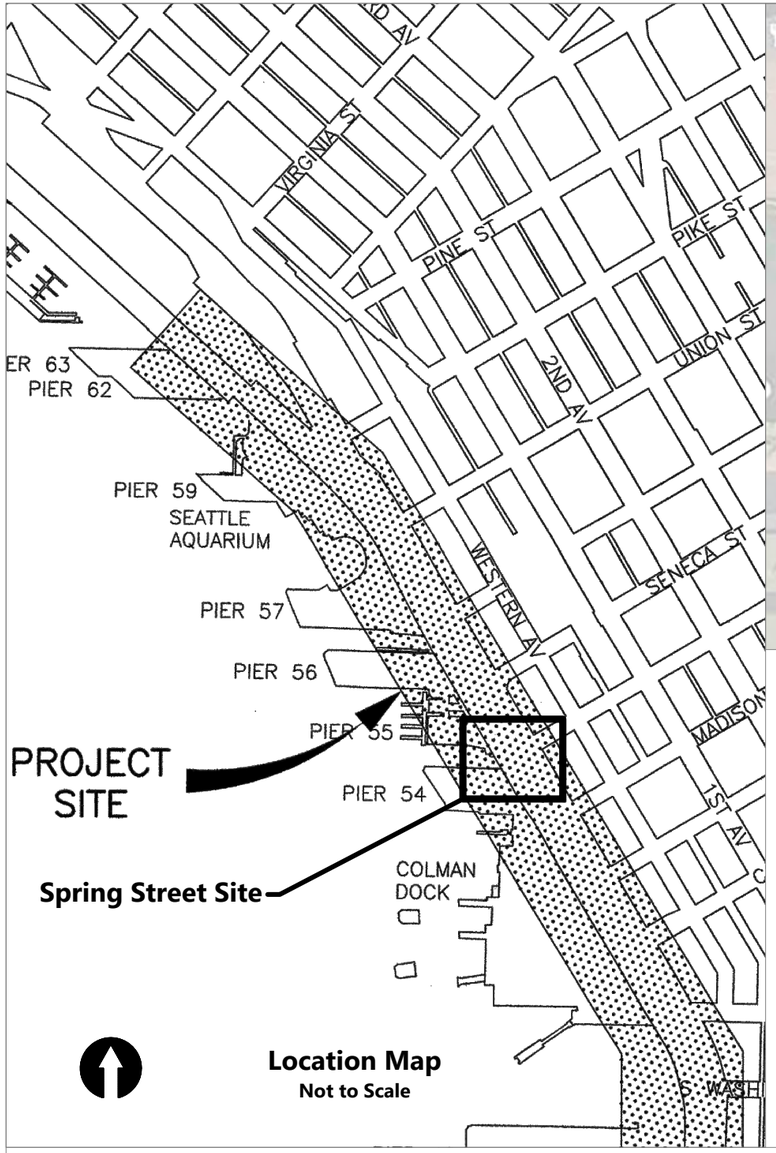
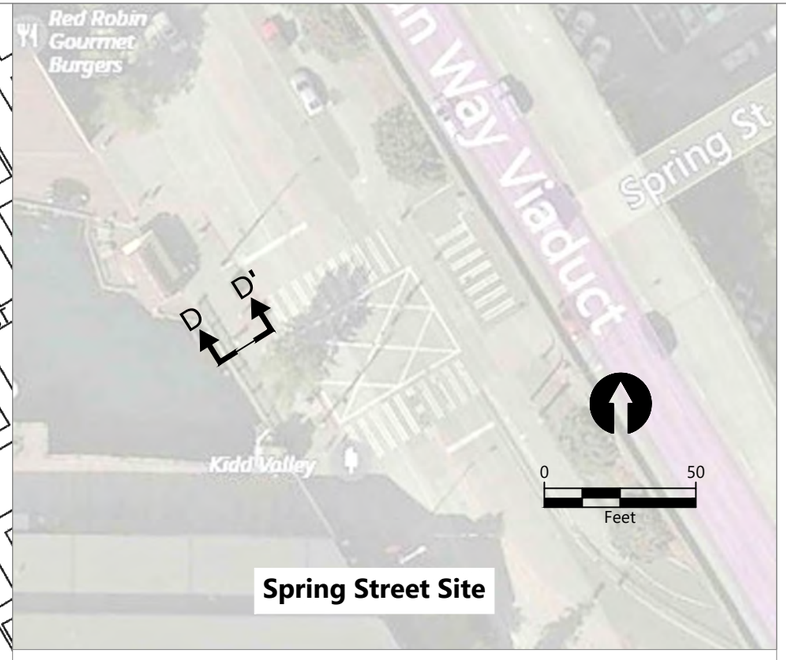
Filepath: \\fuji\anchor\Projects\EBSP\Construction Management\Post-Construction Monitoring\Habitat Elevation Survey\Habitat Cross Sections.dwg Figure 10

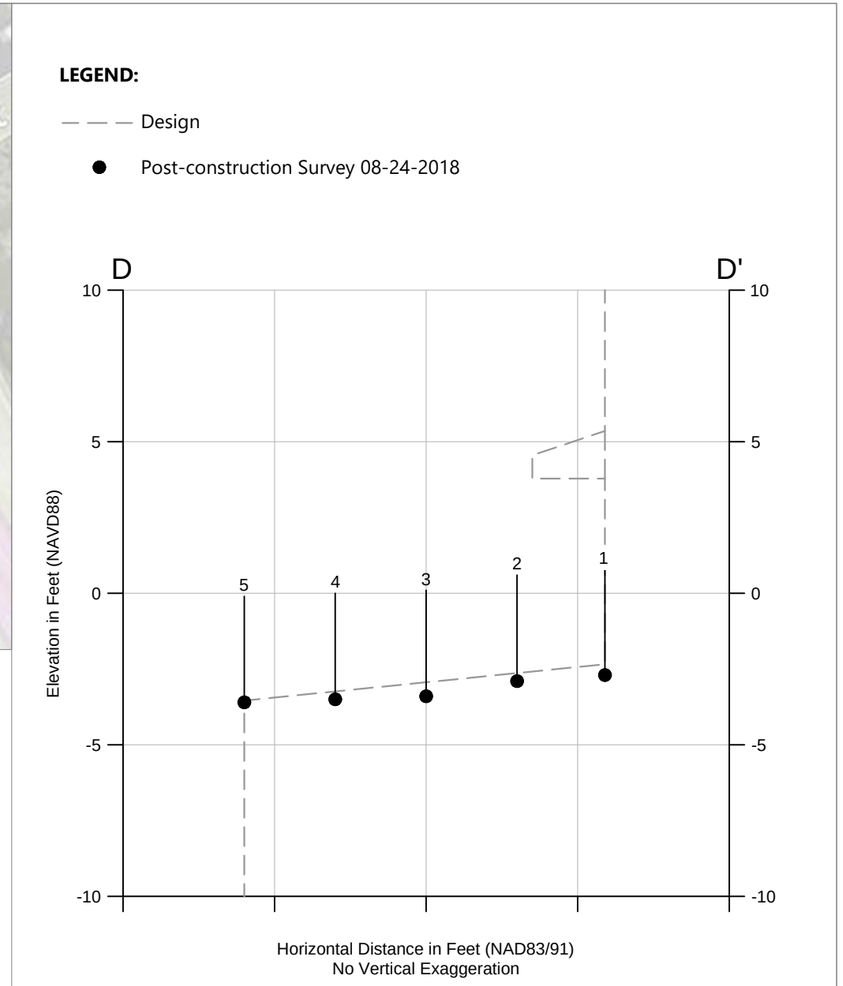




Survey Points Summary Table

D-D'

Point #	Distance from Seawall Face (ft)	NAVD88 Elevation (ft)	MLLW Elevation (ft)
1	0	-2.70	-5.04
2	3	-2.90	-5.24
3	6	-3.40	-5.74
4	9	-3.50	-5.84
5	12	-3.60	-5.94

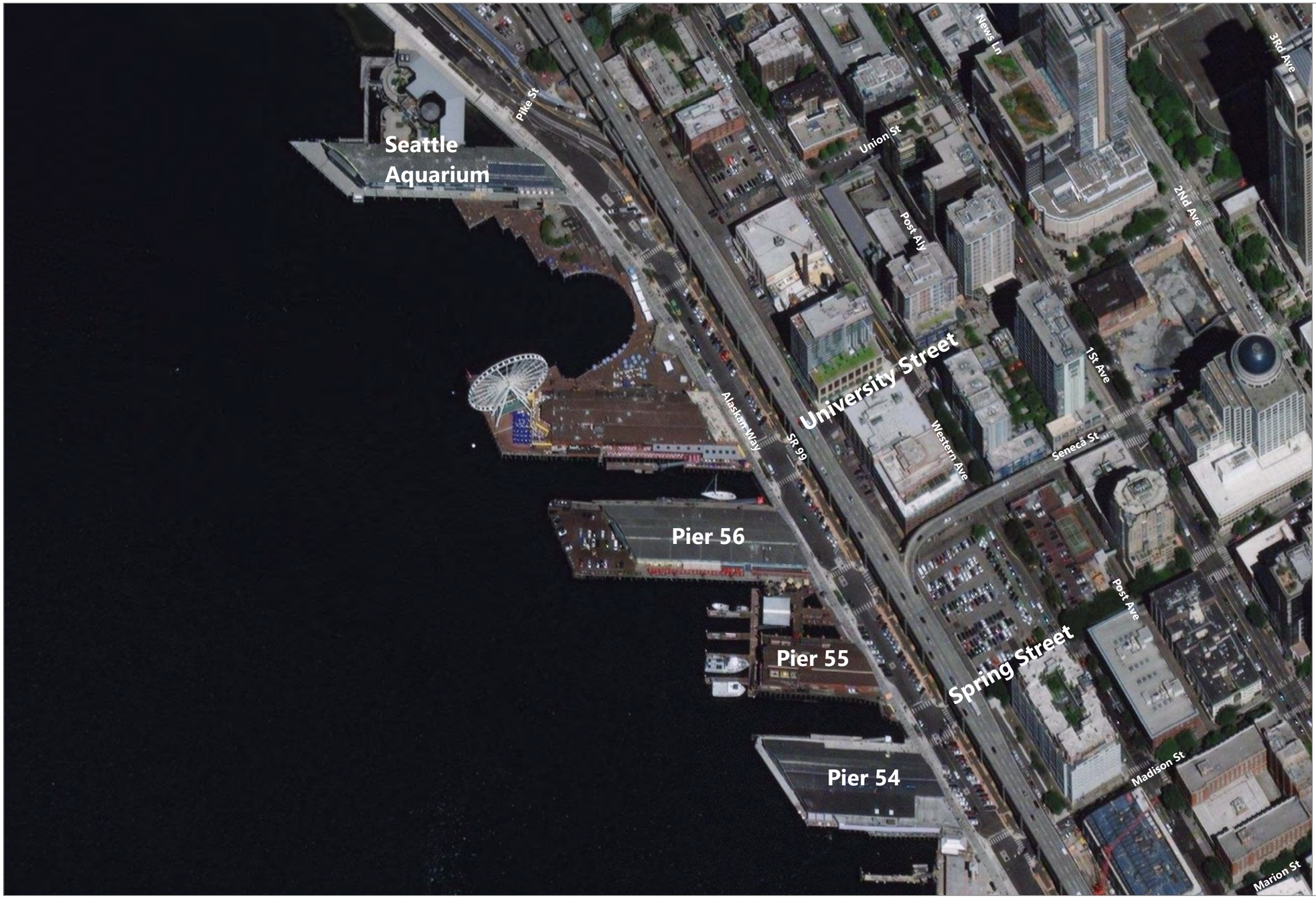


SOURCE: Drawing prepared from Central Seawall Design Drawings by Parsons dated September 2013 and Anchor QEA hand-held level post-construction survey conducted on 08-24-18.

HORIZONTAL DATUM: Local project datum, converted from NAD83/91, Washington State Plane North, NAD83, U.S. Feet.

VERTICAL DATUM: NAVD88 (GEOID 12A), U.S. Feet.

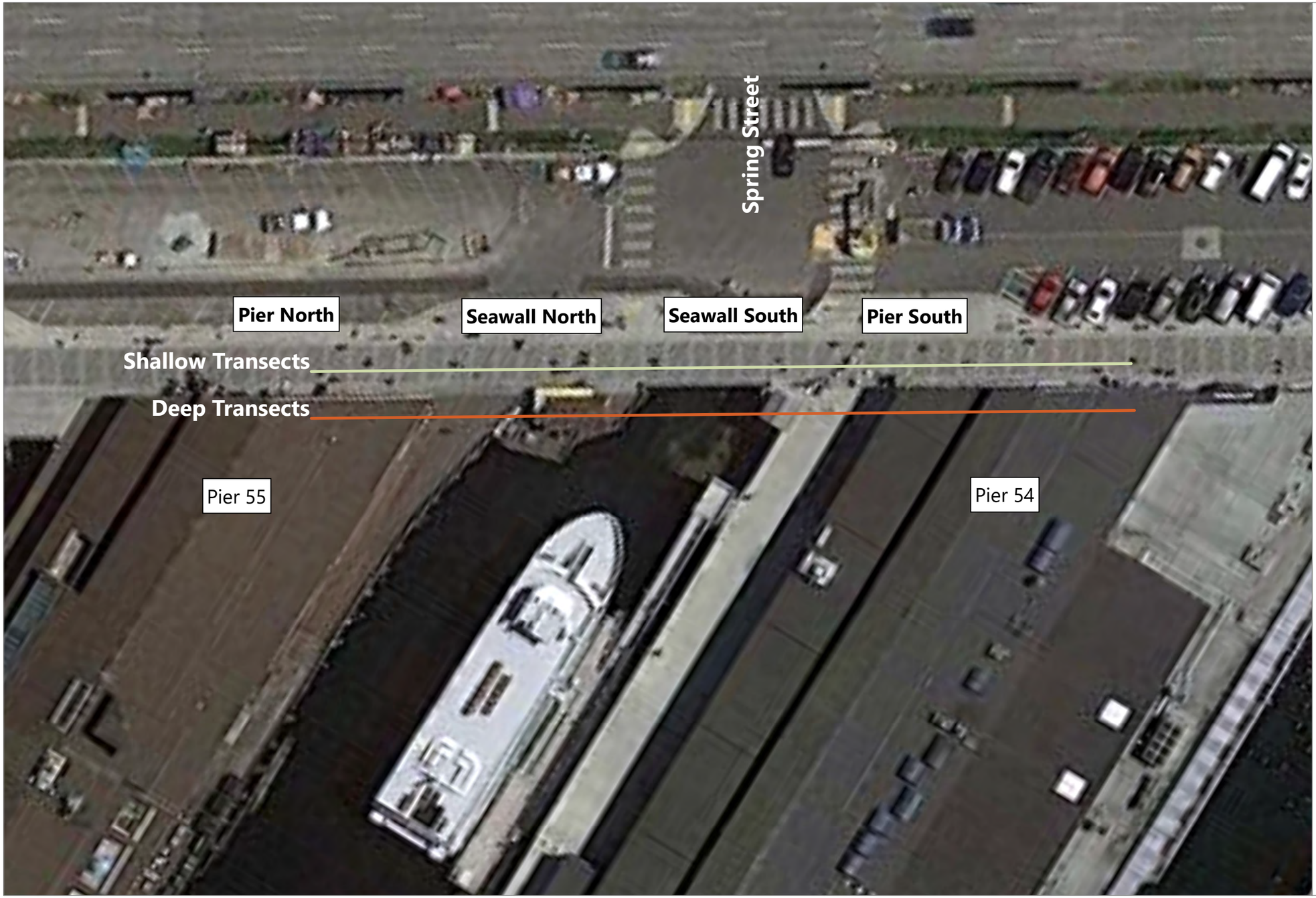
Publish Date: 2018/12/05 12:17 PM | User: acarlson
Filepath: \\fuji\anchor\Projects\EBSP\Construction Management\Post-Construction Monitoring\Habitat Elevation Survey\Habitat Cross Sections.dwg Figure 11



Publish Date: 2019/01/15, 2:38 PM | User: ckiblinger
Filepath: \\orcas\gis\Jobs\JacobsEnginGroup_0795\EBSP\Maps\BullKelp\AQ_BullKelp2018_UW_Monitoring_Sites_DDP.mxd

ANCHOR QEA

Figure 14
Epibenthic, Illumination, and Fish Surveys Monitoring Sites
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project



Publish Date: 2019/01/15, 2:38 PM | User: ckiblinger
Filepath: \\orcas\gis\Jobs\JacobsEnginGroup_0795\EBSP\Maps\BullKelp\AQ_BullKelp2018_UW_Monitoring_Sites_DDP.mxd

ANCHOR QEA

Figure 15
Epibenthic, Illumination, and Fish Surveys Monitoring Locations at Spring Street
2018 Post Construction Monitoring Report (Year 1)
Elliott Bay Seawall Project

Figure 16
Average Fish Densities Across Strata During Snorkel Surveys

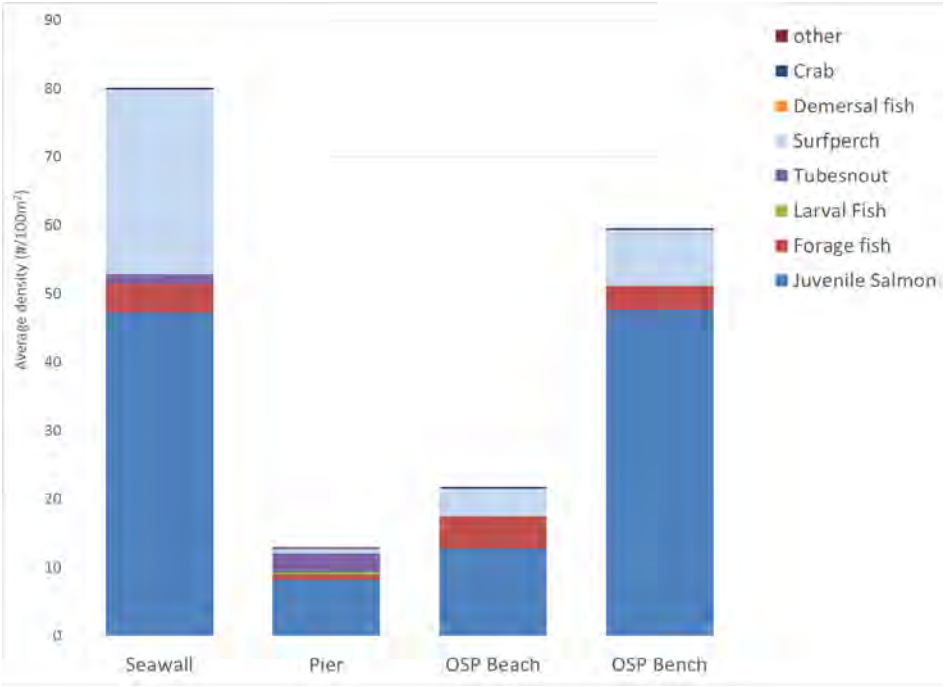


Figure 17
Average Densities for Species Categories of Juvenile Salmon During Snorkel Surveys Across Strata

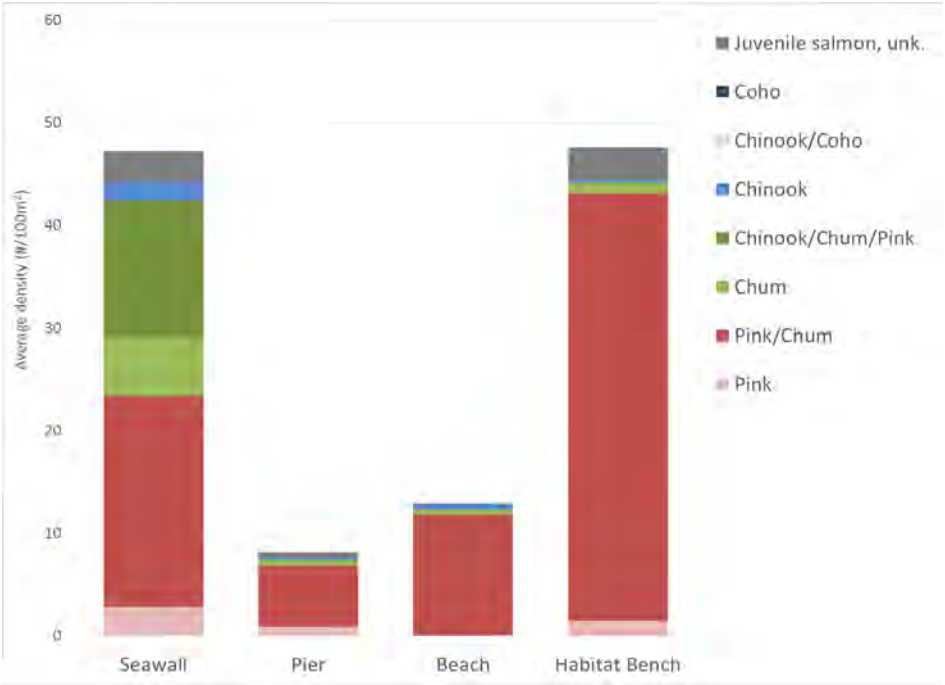


Figure 18
Average Fish Densities During Snorkel Surveys Across Strata, for High and Low Tides, and Shallow and Deep Transects

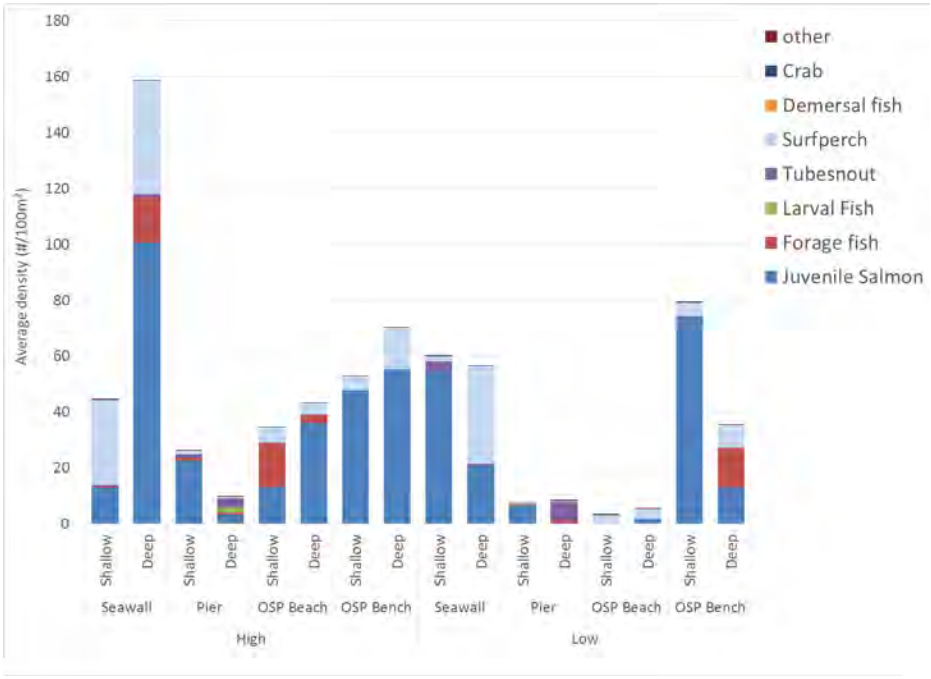


Figure 19
Average Densities of Species Categories of Juvenile Salmon During Snorkel Surveys Across Strata, for High and Low Tides, and Shallow and Deep Transects

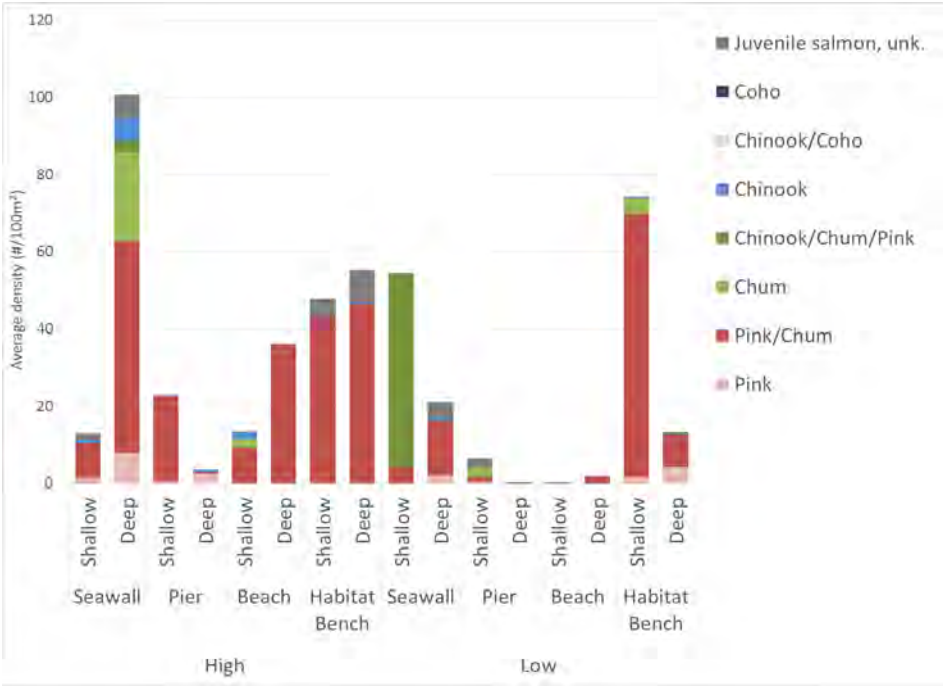
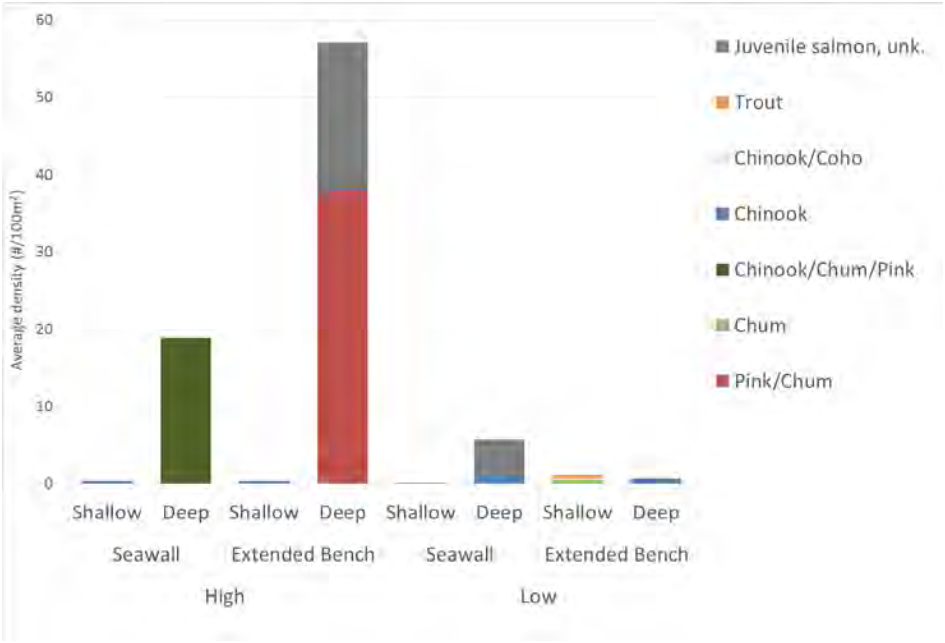
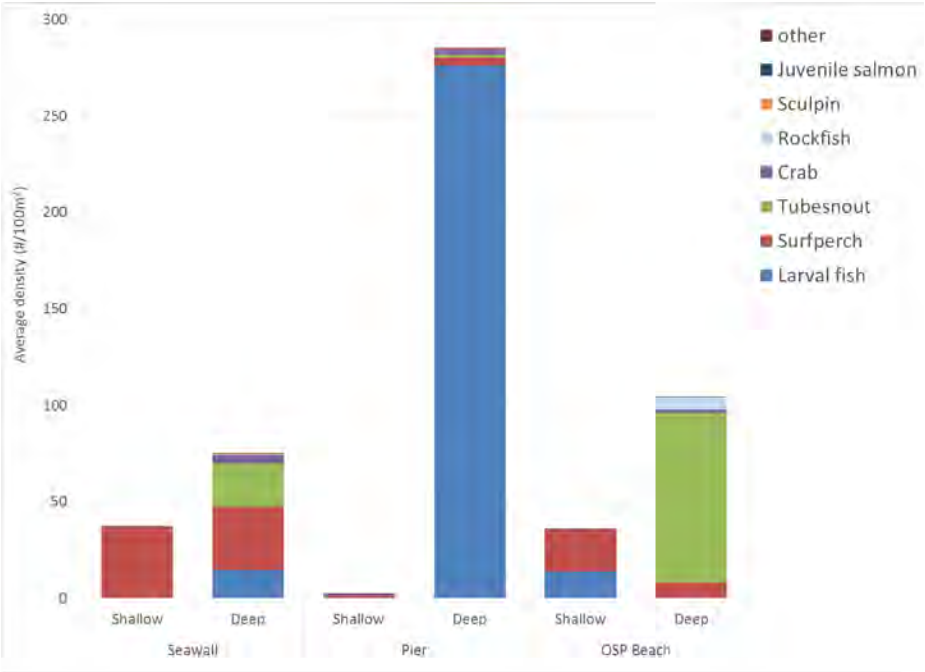


Figure 20
Average Densities of Species Categories of Juvenile Salmon Comparing Snorkel Surveys at the Aquarium Seawall with Those at the Extended Bench from Overlapping Dates May to October 2018



Note: Averages are from each sampling event across strata, for high and low tides, and shallow and deep transects.

Figure 21
Average Fish Densities During SCUBA Surveys Across Strata and Shallow and Deep Transects



Appendix A
Invertebrate and Algal Surveys 2018
Year 1 Monitoring Data Tables

Table A-1

Invertebrate and Algal Aquarium North Uncovered April Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	15	10	30	60	20	15	70	60	35	5	65	30
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	10	5	10	0	15	10	10	5	10	10	10	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	1	2	3	1	1	2	10	0	0	1	15	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	1	0	1	1	0	0	1	1	1	0	0
Tectura scutum	Plate limpet	0	0	0	0	0	0	0	0	1	0	1	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	1	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	1	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	30	0	0	0	5	5	0	0	10
Ulvoid sp	Sea lettuce	3	0	0	0	15	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	1	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	10	2	25	2	2	1	0	0	2	0	5	0
Leathery macrophytes													
Fucus disticus	Rockweed	2	0	0	0	0	0	0	0	1	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	0	0	0	0	0	0	0	0	0	0	0	0
Bare Surface and Barnacle Scars		70	80	30	25	50	70	15	35	50	85	20	65
Total Species Cover[1]		43	20	68	94	55	28	90	71	55	17	96	40

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-2

Invertebrate and Algal Aquarium North Covered April Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	45	40	70	60	50	60	60	60	40	50	70	55
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	2	0	1	0	1	0	1	0	1	0	0	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	5	0	0	0
Mytilus sp.	Mussels	1	1	1	0	1	1	1	0	1	1	1	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	0	0	0	0
Tectura scutum	Plate limpet	0	0	0	0	0	0	0	0	0	0	0	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	0	0	0	0	0	0	0	1	0	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	0	0	0	0	0	0	0	0	0	0	0	0
Bare Ground/Barnacle Scars		50	60	30	40	50	40	40	40	60	50	30	45
Total Species Cover[1]		48	41	72	60	52	61	62	60	48	51	71	55

Notes:
1. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-3

Invertebrate and Algal Pier 55 Uncovered April Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	10	10	40	15	5	5	35	10	10	15	35	10
Chthamalus dalii	Little brown barnacle	0	0	0	15	0	0	0	10	0	0	0	10
Semibalanus cariosus	Thatched barnacle	2	1	1	0	0	0	1	0	0	1	5	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	0	1	0	0	0	0	0	0	0	1	0	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	0	0	0	0
Tectura scutum	Plate limpet	2	1	1	1	0	0	2	1	1	0	1	1
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	5	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	1	0	0	0	0	0	0	0	0	0	0	0
Ulvoid sp	Sea lettuce	1	0	0	0	1	0	0	0	2	0	3	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	1	0	0	0	10	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	1	1	0	0	0	1	0	0	0	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	95	0	30	0	95	95	30	0	90	85	60	0
Bare Surface and Barnacle Scars		85	85	60	70	95	95	60	80	75	85	55	80
Total Species Cover[1]		16	14	43	31	7	5	39	21	28	17	44	21

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-4

Invertebrate and Algal Pier 55 Covered April Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	30	0	5	5	25	5	5	5	0	5
Balanus glandula	Acorn barnacle	10	5	30	5	10	10	40	15	15	15	30	15
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	5	0	1	0	1	1	5	0	1	1	5	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	5	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	5	0	0	0	0	0	0	0
Mytilus sp.	Mussels	0	1	1	0	0	0	1	0	0	0	0	0
Tube worms[1]	Tube worms	1	1	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	0	0	0	0
Tectura scutum	Plate limpet	0	1	0	0	3	0	0	0	0	0	0	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	5	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	5	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	0	0	0	0	0	0	0	0	0	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	50	0	0	0	95	85	0	0	95	0	20	0
Bare Ground/Barnacle Scars		85	95	40	95	80	85	30	80	80	80	65	80
Total Species Cover[2]		16	8	62	5	39	16	71	20	21	21	35	20

Notes:
1. Tube worms are empty, old casings
2. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-5

Invertebrate and Algal Aquarium North Uncovered June Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	80	30	65	55	40	15	60	60	10	40	45	70
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	5	20	0	0	15	25	0	0	50	10	1	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	15	20	35	15	30	15	40	10	15	35	55	10
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	1	1	1	1	1	1	1	1	1	0	1	0
Tectura scutum	Plate limpet	0	0	0	0	0	0	0	0	0	0	0	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	1	0	0	5	0	1	0	10
Ulva linza	Green string lettuce	0	15	0	30	0	65	0	35	60	0	0	70
Ulvoid sp	Sea lettuce	0	0	0	0	5	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	5	5	1	0	1	0	0	0	5	5	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	5	0	0	0	0	0	0	0	0	5	0	0
Microalgae													
Biofilm	Diatons/Bacteria	0	0	0	0	0	0	0	0	0	0	0	0
Bare Surface and Barnacle Scars		5	25	0	20	15	10	0	15	20	20	0	5
Total Species Cover[1]		111	91	102	101	93	121	101	111	141	96	102	160

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-6

Invertebrate and Algal Aquarium North Covered June Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	20	10	0	0	5	0	0	0	10	0	0	0
Balanus glandula	Acorn barnacle	50	70	80	85	75	60	85	80	70	85	85	90
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	0	0	0	1	1	0	1	0	0	0	0	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	25	5	1	0	30	85	0	0	25	75	0	0
Mytilus sp.	Mussels	0	0	0	0	0	0	0	0	0	0	1	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	1	0	0	0
Tectura scutum	Plate limpet	0	0	0	0	0	0	0	0	0	0	0	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	0	0	0	0	0	0	0	0	0	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	0	0	0	0	0	0	0	0	0	0	0	0
Bare Ground/Barnacle Scars		5	15	20	15	20	5	15	20	10	5	15	10
Total Species Cover[1]		95	85	81	86	111	145	86	80	106	160	86	90

Notes:
1. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-7

Invertebrate and Algal Pier 55 Uncovered June Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	0	20	60	15	5	5	70	5	10	15	70	5
Chthamalus dalii	Little brown barnacle	0	0	0	10	0	0	0	5	0	0	0	10
Semibalanus cariosus	Thatched barnacle	15	5	0	0	1	0	1	0	1	1	1	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	1	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	0	1	5	0	1	0	1	0	0	1	1	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	0	0	0	0
Tectura scutum	Plate limpet	0	1	1	5	1	0	1	5	1	1	1	5
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	15	0	0	0	0	0
Porphyra sp2	Red algae	0	0	5	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	20	0	20	0	10	0	30	0	25	0	0
Ulvoid sp	Sea lettuce	50	0	25	60	5	5	65	60	5	0	5	50
Filamentous algae													
Bangia sp.	Red hair	15	0	0	0	5	0	0	0	5	5	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	1	10	5	0	0	0	0	0	0	5	10
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	80	90	0	0	85	95	0	0	85	90	0	0
Bare Ground/Barnacle Scars		20	60	10	10	80	80	5	10	80	55	20	20
Total Species Cover[1]		80	48	106	115	19	20	153	105	22	48	83	80

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-8

Invertebrate and Algal Pier 55 Covered June Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	1	0	0	0	5	0	1	0	1	0	0	0
Balanus glandula	Acorn barnacle	25	15	55	20	20	1	60	10	15	20	60	5
Chthamalus dalii	Little brown barnacle	0	0	0	15	0	0	0	10	0	0	0	5
Semibalanus cariosus	Thatched barnacle	1	5	1	0	1	10	1	5	1	1	5	1
Ascidiacea	Ascidian/Sea squirt	10	25	10	0	5	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	0	1	5	1	0	1	10	1	0	0	1	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	0	0	0	0	0	0	0	0	0	0
Tectura scutum	Plate limpet	0	0	0	0	5	1	0	0	1	0	0	5
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	1	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	0	0	0	0	1	5	15	0	5	15	20
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	70	0	0	0	95	75	0	0	95	80	0	0
Bare Ground/Barnacle Scars		65	55	30	65	65	90	25	60	80	75	20	65
Total Species Cover[1]		38	46	71	36	36	14	77	41	18	26	81	36

Notes:
1. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-9

Invertebrate and Algal Aquarium North Uncovered August Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Balanus glandula	Acorn barnacle	25	15	15	15	25	15	25	50	30	15	25	20
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	15	15	5	2	30	15	40	0	15	15	15	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus sp.	Mussels	0	0	1	0	1	0	1	0	2	2	40	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	5	1	5	5	5	2	2	0	5	5	10	0
Tectura scutum	Plate limpet	5	1	0	0	1	5	0	0	0	0	1	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	1	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	1	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	35	0	0	1	40	0	15	0	45	0	25
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	1	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	30	30	30	30	15	10	10	20	10	10	5	50
Leathery macrophytes													
Fucus disticus	Rockweed	15	0	0	0	10	0	0	0	10	1	0	0
Microalgae													
Biofilm	Diatons/Bacteria	0	0	0	0	0	0	0	5	0	0	0	0
Bare Ground/Barnacle Scars		30	35	45	50	20	30	20	30	25	25	15	5
Total Species Cover[1]		96	97	56	52	88	87	78	85	74	93	96	95

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-10

Invertebrate and Algal Aquarium North Covered August Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	0	10	0	0	5	0	0	0	5	0	0	0
Balanus glandula	Acorn barnacle	50	50	55	80	40	60	55	80	45	70	60	80
Chthamalus dalii	Little brown barnacle	0	0	0	0	0	0	0	0	0	0	0	0
Semibalanus cariosus	Thatched barnacle	0	0	5	0	0	0	1	0	1	0	2	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	55	60	10	0	75	90	15	0	70	90	10	0
Mytilus sp.	Mussels	0	1	0	0	1	1	0	0	1	1	1	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	5	1	1	0	2	0	1	0	2	0	1	0
Tectura scutum	Plate limpet	0	0	0	0	0	0	0	0	0	0	0	0
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	1	0	0	0	0	0	0	0	0	1	0
Ulvoid sp	Sea lettuce	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	1	0	1	0	0	0	2	0	2	0	0	0
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	5	0	0	0	0	0	0	0	0	0	0	0
Bare Ground/Barnacle Scars		20	30	30	20	30	10	40	20	10	10	30	20
Total Species Cover[1]		111	123	72	80	123	151	74	80	126	161	75	80

Notes:
1. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-11

Invertebrate and Algal Pier 55 Uncovered August Monitoring Data

Scientific Name	Common Name	Percent Cover											
		T1LS	T1LW	T1US	T1UW	T2LS	T2LW	T2US	T2UW	T3LS	T3LW	T3US	T3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	5	0	0	0	5	0	0	0	5	0	0	0
Balanus glandula	Acorn barnacle	15	25	50	20	20	20	70	20	15	20	50	10
Chthamalus dalii	Little brown barnacle	0	0	0	5	0	0	0	5	0	0	0	10
Semibalanus cariosus	Thatched barnacle	0	1	1	0	1	0	2	0	2	2	2	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	5	0	0	0	2	0	0	0	0	5	0	0
Mytilus sp.	Mussels	0	0	0	5	0	0	5	0	0	0	2	0
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	1	1	1	5	5	1	5	5	2	1	1	1
Tectura scutum	Plate limpet	0	0	0	5	0	0	0	10	0	0	1	5
Littorins sp.	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	1	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	50	1	0	1	30	0	0	0	20	0	0
Ulvoid sp	Sea lettuce	70	1	15	40	20	25	50	50	50	5	20	15
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	5	0	0	0	5	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	0	0	25	10	0	0	30	10	0	2	30	10
Leathery macrophytes													
Fucus disticus	Rockweed	1	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	10	60	0	0	25	95	0	0	30	40	0	0
Bare Ground/Barnacle Scars		30	25	10	10	40	70	0	10	30	45	20	60
Total Species Cover[1]		97	78	93	90	59	77	162	100	79	55	106	51

Notes:
1. Some species may overlap
LS: lower shelf
LW: lower wall
T: transect
US: upper shelf
UW: upper wall

Table A-12

Invertebrate and Algal Pier 55 Covered August Monitoring Data

Scientific Name	Common Name	Percent Cover											
		CT1LS	CT1LW	CT1US	CT1UW	CT2LS	CT2LW	CT2US	CT2UW	CT3LS	CT3LW	CT3US	CT3UW
Sessile Invertebrates													
Balanus crenatus	Crenulated barnacle	2	0	0	0	0	0	0	0	5	2	0	0
Balanus glandula	Acorn barnacle	30	15	50	15	25	15	60	15	30	15	60	10
Chthamalus dalii	Little brown barnacle	0	0	0	5	0	0	0	5	0	0	0	5
Semibalanus cariosus	Thatched barnacle	0	1	2	1	0	1	5	0	0	1	2	0
Ascidiacea	Ascidian/Sea squirt	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoan	Bryozoan	90	90	50	0	90	5	40	0	50	20	20	0
Mytilus sp.	Mussels	0	0	1	0	0	0	5	5	0	0	10	1
Tube worms	Tube worms	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Invertebrates													
Lottia pelta	Shield limpet	0	0	1	1	0	1	1	0	0	0	1	1
Tectura scutum	Snails/Periwinkles	0	0	0	0	0	0	0	0	0	0	0	0
Littorins sp.	Plate limpet	0	0	0	0	5	0	0	0	0	0	0	0
Mopalia muscosa	Mossy chiton	0	0	0	0	0	0	0	0	0	0	0	0
Foliose algae													
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	15	0	0
Ulvoid sp	Sea lettuce	0	0	0	5	1	0	0	0	5	1	0	0
Filamentous algae													
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes													
Mastocarpus papillatus	Black tar	10	0	10	5	2	50	25	10	0	0	25	15
Leathery macrophytes													
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0	0	0
Microalgae													
Biofilm	Diatons/Bacteria	70	0	0	0	0	0	0	0	90	80	0	0
Bare Ground/Barnacle Scars		5	15	5	70	5	50	15	70	10	45	20	70
Total Species Cover[1]		132	106	114	32	123	72	136	35	90	54	118	32

Notes:
1. Some species may overlap
CT: covered transect
LS: lower shelf
LW: lower wall
US: upper shelf
UW: upper wall

Table A-13

Macroalgae Aquarium North Uncovered August Monitoring Data

Scientific Name	Common Name	Percent Cover									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Foliose algae											
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	10	10	10	10	20
Ulvoid sp [1]	Sea lettuce	50	50	50	60	60	85	80	90	90	80
Filamentous algae											
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes											
Mastocarpus papillatus	Turkish washcloth	0	0	0	0	10	0	0	5	0	10
Mazaella splendens	Iridescent weed	0	0	0	0	0	0	0	5	0	10
Leathery macrophytes											
Costaria costata	Five-ribbed kelp	0	0	0	0	0	0	0	0	0	0
Fucus disticus	Rockweed	0	0	0	0	0	0	0	0	0	0
Bare Ground		50	50	50	40	30	5	10	0	0	0
Total Species Cover[2]		50	50	50	60	70	95	90	110	100	120

Notes:

1. Both attached and unattached algae observed
2. Some species may overlap

B: bench quadrat; B1 to B5 is Bench and B6 to B10 is Expanded Bench

Table A-14

Macroalgae Aquarium North Covered August Monitoring Data

Scientific Name	Common Name	Percent Cover									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Foliose algae											
Porphyra sp1	Red algae	0	0	0	0	0	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0	0	0	0	0	0
Ulvoid sp [1]	Sea lettuce	10	10	0	0	0	0	0	0	0	0
Filamentous algae											
Bangia sp.	Red hair	0	0	0	0	0	0	0	0	0	0
Corticated macrophytes											
Mastocarpus papillatus	Turkish washcloth	0	0	0	0	0	0	0	0	0	0
Mazaella splendens	Iridescent weed	0	0	0	0	0	0	0	0	0	0
Leathery macrophytes											
Costaria costata	Rockweed	0	0	0	0	0	0	0	0	0	0
Fucus disticus	Five-ribbed kelp	0	0	0	0	0	0	0	0	0	0
Bare Ground		90	90	100	100	100	100	100	100	100	100
Total Species Cover[2]		10	10	0	0	0	0	0	0	0	0

Notes:

1. Both attached and unattached algae observed
2. Some species may overlap

B: bench quadrat; B1 to B5 is Bench and B6 to B10 is Expanded Bench

Table A-15

Macroalgae Pier 55 Uncovered August Monitoring Data

Scientific Name	Common Name	Percent Cover				
		B1	B2	B3	B4	B5
Foliose algae						
Porphyra sp1	Red algae	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0
Ulvoid sp [1]	Sea lettuce	5	60	40	40	90
Filamentous algae						
Bangia sp.	Red hair	0	0	2	0	0
Corticated macrophytes						
Mastocarpus papillatus	Turkish washcloth	0	0	0	0	10
Mazaella splendens	Iridescent weed	0	5	0	0	0
Leathery macrophytes						
Fucus disticus	Rockweed	0	0	0	0	0
Costaria costata	Five-ribbed kelp	0	0	0	0	0
Bare Ground		95	35	60	40	0
Total Species Cover[2]		5	65	42	60	100

Notes:

1. Both attached and unattached algae observed
2. Some species may overlap

B: bench quadrat; B1 to B5 is Bench

Table A-16

Macroalgae Pier 55 Covered August Monitoring Data

Scientific Name	Common Name	Percent Cover				
		B1	B2	B3	B4	B5
Foliose algae						
Porphyra sp1	Red algae	0	0	0	0	0
Porphyra sp2	Red algae	0	0	0	0	0
Ulva linza	Green string lettuce	0	0	0	0	0
Ulvoid sp [1]	Sea lettuce	0	0	0	0	0
Filamentous algae						
Bangia sp.	Red hair	0	0	0	10	15
Corticated macrophytes						
Mastocarpus papillatus	Turkish washcloth	0	0	0	0	0
Mazaella splendens	Iridescent weed	0	0	0	0	0
Leathery macrophytes						
Fucus disticus	Rockweed	0	0	0	0	0
Costaria costata	Five-ribbed kelp	0	0	0	0	0
Bare Ground		100	100	100	90	85
Total Species Cover[2]		0	0	0	10	15

Notes:

1. Both attached and unattached algae observed
2. Some species may overlap

B: bench quadrat; B1 to B5 is Bench

Appendix B
Epibenthic, Illumination, and Fish Surveys 2018 Year 1 Monitoring Data Tables and Photographs

Table B1
Average Light Measurements of Photosynthetically Active Radiation from Focused Measurements Taken Between Piers, Along Pier Edges, and Underneath Piers During Sunny, Partly Cloudy, and Cloudy Weather Conditions from May to July 2018

Weather	Strata	Water Depth (meters)	PAR[1]	Light Ratio[2]
Sunny	Seawall	air	8.3%	
		0.3	5.1%	
		1	4.7%	
		2	5.1%	
	Edge	air	5.3%	
		0.3	2.7%	
		1	2.1%	
		2	1.4%	
	Pier	air	2.1%	2.4
		0.3	1.5%	6.1
		1	1.1%	4.3
		2	0.7%	2.8
Partly Cloudy	Seawall	air	13.6%	
		0.3	7.3%	
		1	7.6%	
		2	5.9%	
	Edge	air	9.2%	
		0.3	6.2%	
		1	8.8%	
		2	12.7%	
	Pier	air	2.4%	1.7
		0.3	1.3%	2.8
		1	0.9%	2.6
		2	0.5%	1.6
Cloudy	Seawall	air	31.9%	
		0.3	19.3%	
		1	16.2%	
		2	11.7%	
	Edge	air	10.6%	
		0.3	6.8%	
		1	5.1%	
		2	3.4%	

Weather	Strata	Water Depth (meters)	PAR[1]	Light Ratio[2]
	Pier	air	1.9%	1.8
		0.3	1.1%	2.9
		1	0.7%	1.9
		2	0.5%	1.4

Note:

1. PAR is expressed as percent of ambient light (measured above the sidewalk).
2. Light Ratio is the amount of light below LPS associated with piers compared to deeper pier sections without LPS (e.g., 2.4 = 2.4 x more light under LPS).

Table B2
Average Light Measurements of Photosynthetically Active Radiation During Perpendicular Transect Extensive Measurements April to May 2018, Starting at 1 Meter from the Seawall

Site	Strata	Water Depth (meters)	1m	2	3	4	5	6	7	8	9	10	Above LPS
Aquarium		Above LPS											2,508.0
	Pier	Air	41.9	37.0	37.6	40.7	32.9	37.0	27.3				
		0.3	22.6	20.4	13.0	6.4	3.6	5.3	3.3				
		1	34.0	20.6	16.4	4.1	3.6	3.8	3.1				
		2	21.8	17.7	11.9	3.8	3.3	4.0	4.4				
	Seawall	Air	283.8	310.9	770.7	1,564.2	1,607.5	1,629.7	1,866.6	958.4	1,610.0	241.7	
		0.3	89.2	94.8	526.9	871.7	917.7	923.0	1,014.3	913.3	1,218.6	2,060.0	
		1	101.0	88.8	498.5	709.0	602.3	739.1	783.3	636.4	1,377.8	1,293.7	
		2	65.3	65.7	419.6	521.5	475.1	665.5	637.5	463.1	946.4	1,552.3	
Spring	Pier-N	Above LPS											180.8
		Air	5.4	18.6	4.4	13.7	3.1	4.0	3.9	1.6	5.0	5.0	
		0.3	3.7	16.1	3.0	8.4	1.7	1.9	2.2	1.1	3.1	2.7	
		1	2.6	12.1	3.1	9.8	1.7	2.0	2.0	1.7	2.8	2.9	
		2	2.0	5.0	3.1	9.1	1.8	2.8	2.3	1.5	3.5	3.8	
	Pier-S	Above LPS											216.6
		Air	5.2	49.7	4.6	11.2	6.8	6.9	8.1	10.2	11.6	13.0	
		0.3	3.2	8.5	5.3	5.9	2.5	2.0	2.2	3.0	3.9	5.2	
		1	2.9	12.1	3.9	8.8	3.0	1.8	1.8	2.0	2.8	3.5	
		2	1.8	5.1	3.2	5.8	2.6	1.6	1.5	2.2	2.9	2.4	

Site	Strata	Water Depth (meters)	1m	2	3	4	5	6	7	8	9	10	Above LPS
	Seawall	Above LPS											2,298.0
		Air	146.3	122.5	1,997.3	1,897.5	2,325.0	2,361.0	2,401.0	2,412.0	2,392.0	2,373.0	
		0.3	1,110.1	37.6	1,562.0	148.2	1,662.5	1,655.8	1,664.7	1,613.7	1,624.5	1,628.8	
		1	1,164.0	35.7	1,176.6	153.6	1,213.6	1,191.7	1,226.9	1,222.6	1,224.4	1,224.4	
		2	787.6	87.9	858.4	131.0	847.2	887.8	916.6	898.6	880.7	859.8	
University	Pier	Above LPS											198.2
		Air	3.9	16.9	3.1	9.8	0.5	0.6	0.3	0.3	0.2	0.8	
		0.3	6.6	14.0	2.7	7.3	0.3	0.1	0.1	0.1	0.1	0.1	
		1	4.2	7.9	2.0	2.4	0.5	0.1	0.1	0.0	0.0	0.0	
		2	1.7		1.7		0.5	0.2	0.1	0.0	0.0	0.0	
	Seawall	Above LPS											2,237.0
		Air	170.1	181.2	2,271.0	2,297.0	2,335.0,	2,455.0	2,473.0	2,443.0	2,428.0	2,463.0	
		0.3	110.6	159.3	1,742.0	1,781.8	1,841.9	1,774.3	1,824.9	1,756.0	1,814.9	1,849.4	
		1	49.9	113.1	1,346.9	1,375.2	1,430.2	1,373.1	1,397.5	1,340.4	1,323.9	1,372.4	

Note:
Measurements were all during cloudy or partly cloudy conditions.

Table B3
Average Light Measurements of Photosynthetically Active Radiation During Parallel Transect Extensive Measurements April to May 2018

Site	Transect Depth	Water Depth (meters)	-25m	-20	-15	-10	-5	-1	0	1	5	10	15	20	24	25
Spring	Shallow	Air	32.6	29.6	29.4	34.2	28.5	43.5	172.9	125.3	145.0	122.5	66.2	113.3	47.5	20.0
		0.3	18.4	11.1	12.5	12.3	23.4	14.8	20.9	37.1	67.2	37.6	14.1	14.9	17.0	122.6
		1	9.9	7.7	8.4	12.1	14.1	19.6	13.6	36.5	50.5	35.7	18.5	6.1	10.4	7.6
		2	4.7	4.3	4.0	5.1	5.1	12.5	18.4	85.6	130.5	87.9	25.7	8.5	6.6	5.2
	Deep	Air	9.6	15.1	10.6	12.5	14.7	22.3	30.5	154.6	2,345.0	1,897.5	60.9	19.8	25.3	28.4
		0.3	8.6	8.7	8.4	7.2	7.1	13.5	16.1	114.4	138.4	148.2	25.7	13.4	10.0	9.6
		1	7.4	7.3	10.3	9.3	9.1	13.0	12.3	93.6	133.3	153.6	28.4	16.8	13.6	12.4
		2	4.7	5.3	4.3	7.4	7.2	13.0	15.2	103.5	125.6	131.0	64.9	22.3	12.3	9.7
University	Shallow	Air	14.7	17.8	17.3	16.9	25.0	41.8	59.2	78.4	130.4	151.1	187.6	187.0		111.5
		0.3	12.3	13.5	15.0	14.0	18.7	32.3	41.6	51.2	112.5	149.7	189.7	191.7		134.2
		1	7.5	7.0	8.7	7.9	12.0	23.7	29.2	36.6	82.0	112.1	162.8	141.7		115.3
	Deep	Air	7.7	8.5	11.3	9.8	16.0	78.6	99.2	206.6	409.5	518.4	499.6	537.5		372.0
		0.3	3.4	5.1	4.4	7.3	6.9	39.6	63.3	78.4	232.9	342.6	343.6	319.7		228.0
		1	2.1	1.4	2.2	2.4	3.8	22.6	51.3	115.3	144.4	226.8	247.5			160.7
Aquarium	Shallow	Air	14.8	11.7	16.8	17.4	55.0	111.6	84.2	125.9	140.5	285.7	178.6	288.9		221.6
		0.3	5.1	6.4	6.7	36.2	20.6	55.7	31.2	60.3	61.9	123.8	84.0	94.9		74.5
		1	5.4	3.4	4.1	4.0	16.6	62.7	33.7	45.9	72.3	117.5	85.8	85.9		75.3
		2	3.8	2.7	3.4	2.6	12.2	54.6	28.8	35.0	57.7	88.8	64.4	41.8		93.8
	Deep	Air	7.9	8.6	14.3	16.6	101.6	126.5	384.6	411.5	505.1	608.3	656.9	2,674.0		2,621.0
		0.3	4.7	2.4	3.1	2.4	37.0	69.4	248.9	209.4	286.4	378.2	315.3	1,893.9		1,808.8
		1	2.2	1.6	2.0	2.4	33.4	48.8	189.1	156.8	234.0	264.7	221.0	1,738.0		1,618.8
		2	1.5	1.5	1.8	2.2	30.1	32.9	117.4	103.3	453.9	155.3	150.7	606.2		1,301.6
OSP	Shallow	Air							980.7							

Site	Transect Depth	Water Depth (meters)	-25m	-20	-15	-10	-5	-1	0	1	5	10	15	20	24	25
		0.3							531.2							
		1							385.2							
		2							251.1							

Notes:
Measurements were all during cloudy or partly cloudy conditions. Negative points on the transect are beneath a pier with zero representing the pier edge, and positive values along open seawall strata between piers. At the Spring street site, the negative points on the transect are under the south pier (pier 54); transect point 24m is 1m from the north pier edge, and 25m is at the edge of the north pier (pier 55). Transect points 15 and 20m are under the overhead deck associated with the Frankfurter food stand.

Table B4
Average Monthly Surface and Bottom Water Salinity and Temperature During Snorkel Surveys

Month	Surface Salinity (ppt)	Surface Temperature (°C)	Bottom Salinity (ppt)	Bottom Temperature (°C)
March	25.0	8.5	27.6	8.5
April	19.9	9.1	25.6	8.9
May	22.1	11.3	26.5	10.4
June	26.6	12.9	27.6	11.9
July	27.1	14.7	28.1	13.4
August	27.8	14.2	28.4	13.7
September	28.2	13.7	28.4	13.7
October	27.1	12.7	28.6	12.8

Table B5
Average of Water Depths at Strata Sampled During Snorkel Surveys

Tide	Strata	Transect Depth	Average of Water Depth (meters)
High	Spring/University sites	Shallow	3.1
		Deep	6.1
	OSP Pocket Beach	Shallow	1.6
		Deep	2.8
	OSP Habitat Bench	Shallow	2.0
		Deep	3.2
	Aquarium Extended Bench	Shallow	2.4
		Deep	2.6
Low	Spring/University sites	Shallow	1.5
		Deep	5.0
	OSP Pocket Beach	Shallow	1.1
		Deep	1.6
	Aquarium Extended Bench	Shallow	1.7
		Deep	2.0
	OSP Habitat Bench	Shallow	1.3
		Deep	2.5

Notes:
At the Spring and University Street sites, shallow transect depths were over the habitat bench and under the LPS, deep transect depths were off the habitat bench over deeper water. At the Aquarium site there is an extended bench farther from shore.

Table B6
Sum of Fish Counts During Snorkel Surveys for Each Sampling Event

Fish Group	Fish Species	March (1)	March (2)	April (1)	April (2)	May (1)	May (2)	June (1)	June (2)	July (1)	July (2)	Aug (1)	Sept (1)	Oct (1)
Juvenile Salmon	Pink	150	60	415		412	4	5						
	Chum/Pink		70	1,864	9,040	2,509	2,566	2						
	Chum	8		150	665	351	6							
	Chinook/Chum/Pink						1,500							
	Chinook					25	292	38	84	25		18	2	2
	Chinook/Coho									2	2			
	Coho								12					
	Trout								6			2		
	Juvenile salmon, unk.	100			500	603	751				4	1	2	
Surfperch	Shiner Perch	1			2,001	3,004	876	663	251	189	92	1,313	1,264	2,525
	Striped Seaperch	1	12	12	21	84	76	116	46	45	14	45	79	46
	Pile Perch			1				23	60	8	10	19	5	15
	Striped Seaperch/Pile Perch				5		5	15						
	Kelp Perch								3		8	4		
	Perch, unk.								1					
Forage fish	Herring						52	65	101	300	500	1,010		2
	Surf Smelt							15	20					
	Forage fish, unk.										40			
Tubesnout	Tubesnout							50		251	400	182	109	110
Crab	Red Rock Crab	1	5	1		4		4	7	7	8	6	20	19
	Kelp Crab	3	17			2	1	4	3	7	3	3	4	13

Fish Group	Fish Species	March (1)	March (2)	April (1)	April (2)	May (1)	May (2)	June (1)	June (2)	July (1)	July (2)	Aug (1)	Sept (1)	Oct (1)
	Crab, unk.						1	7	1	1	4			
	Dungeness Crab								7			2		
	Cheiragonidae crab									1		1		
	Helmet Crab													1
	Graceful Crab											1		
Larval Fish	Larval Fish			1						1	100			
Demersal fish	Sculpin, unk.		1							6				
	Tidepool Sculpin										1	1		2
	Sailfin Sculpin													1
	Buffalo Sculpin													1
	Rockfish, unk.					1								1
	Yellow Rockfish													1
	Ratfish											1		1
	Painted greenling	1												
	Gunnel							1						
	Clingfish									1				
	Red Irish Lord													1
Other	Adult Coho Salmon													10
	Stickleback												8	1
	Fish, unknown										1			
	Pacific Tomcod		1											

Table B7
Average Lengths of Fish Groups During Snorkel Surveys, and Percentage of Water Column Positions of Observations at Surface, Middle, and Bottom

Fish Group	Average of Minimum Length (centimeters)	Surface	Middle	Bottom	Sum
Forage fish	7.5	35.3%	64.7%		17
Juvenile Salmon	6.0	34.7%	64.1%	1.2%	170
Larval Fish	2.5	50.0%		50.0%	2
Tubesnout	6.3	5.0%	60.0%	35.0%	20
Surfperch	10.5	0.4%	43.4%	56.2%	461
Demersal fish	15.0		22.2%	77.8%	18
Crab[1]	10.3		26.1%	73.9%	134

Note:

1. Crabs that were in the middle of the water column were observed on a piling or the seawall.

Table B8
Percent of Fish Feeding During Snorkel Surveys

Strata	Feeding (percent)
Seawall	28%
Pier	24%
OSP Pocket Beach	29%
OSP Habitat Bench	32%

Strata	Depth	Feeding (percent)
Seawall and Pier Strata	Shallow	33%
	Deep	20%

Fish Group	Feeding (percent)
Juvenile Salmon	27%
Forage fish	24%
Tubesnout	15%
Surfperch	13%
Crab	10%
Demersal fish	0%

Salmon Species	Strata	Feeding (percent)
Chinook observations	Seawall	45%
	Pier	38%
	Beach	33%

Salmon Species	Strata	Feeding (percent)
	Habitat Bench	29%
Chum/pink observations	Seawall	30%
	Pier	15%
	Beach	22%
	Habitat Bench	29%

Table B9
Average of Water Depths at Strata Sampled During SCUBA Surveys

Strata	Transect Depth	Average of Water Depth (meters)
Spring/University sites	Shallow	2.4
	Deep	6.0
Aquarium Extended Bench	Shallow	2.0
	Deep	2.8
OSP Pocket Beach	Shallow	2.5
	Deep	5.3

Note:
At the Spring and University Street sites, shallow transect depths were over the habitat bench and under the LPS, deep transect depths were off the habitat bench at the base of the sheet pile supporting the bench. At the Aquarium site there is an extended bench farther from shore.

Table B10
Sum of Fish Counts During SCUBA Surveys for Each Sampling Event

Fish Group	Fish Species	April	May	June	July
Larval fish	Larval fish			5100	2100
Surfperch	Shiner Perch	341	740	97	276
	Striped Seaperch	9	92	109	79
	Pile Perch	5	10	14	31
	Kelp Perch	2	10	14	18
Tubesnout	Tubesnout	1		409	698
Crab	Red Rock Crab	39	18	27	39
	Kelp Crab	6	4	10	18
	Helmet Crab			2	7
	Pygmy rock crab	1		2	2
	Graceful Crab			1	
Rockfish	Black Rockfish			35	12
	Quillback Rockfish			5	1

Fish Group	Fish Species	April	May	June	July
	Rockfish, unknown			1	3
	Brown Rockfish			2	
Sculpin	Sculpin, unknown		1		8
	Tidepool Sculpin				1
	Smoothhead Sculpin		1		
other	Ratfish				2
	Flatfish, unknown			2	
	Pacific Tomcod			1	
	Lingcod				1
	Crescent Gunnel		1		
	Greenling				1
Salmon	Juvenile Salmon				1

Table B11
Average of Fish Group Lengths (Minimum Value of Size Class Range) During SCUBA Surveys, and Percentage of Water Column Positions of Observations on the Bottom, Within 1 Meter of the Bottom, and Middle

Fish Group	Average of Minimum Length (centimeters)	Bottom	Within 1 Meter of Bottom	Middle	Sum
Crab[1]	12.0	91.9%	0.9%	7.2%	111
Sculpin	8.5	100.0%			11
Rockfish	17.3	50.0%	14.3%	35.7%	14
Surfperch	12.3	1.9%	49.0%	49.0%	157
Tubesnout	3.6		48.0%	52.0%	25
Larval fish	0.5		28.6%	71.4%	7
Juvenile salmon	7.5		100.0%		1
Other					
Ratfish	50		100.0%		2
Crescent Gunnel	12.5	100.0%			1
Flatfish, unknown	27.5	50.0%	50.0%		2
Greenling	30		100.0%		1
Lingcod	50	100.0%			1
Pacific Tomcod	10		100.0%		1

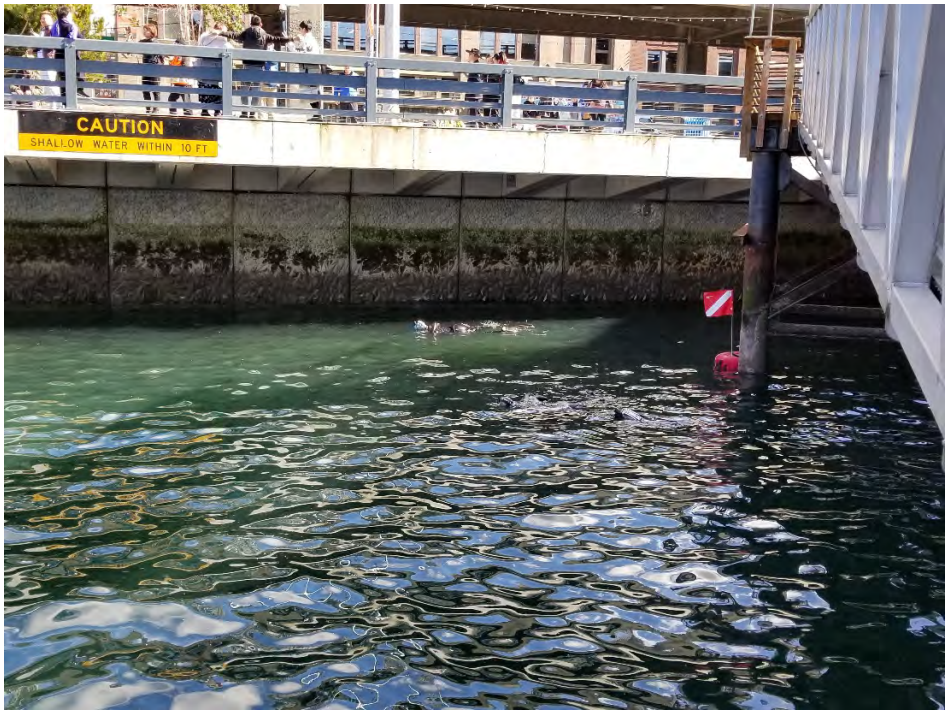
Note:

1. Crabs that were in the middle of the water column were observed on a piling or the seawall.

Table B12
Sum of Fish Densities (#/100m^2) and the Average Percent Composition of Algae in Quadrats Along SCUBA Transects at the Subtidal Substrate Enhancement at Waterfront Park and at an Adjacent Reference Habitat

	Enhancement	Reference
Fish/Crab Species		
Red Rock Crab	0.6	2.2
Pacific Sanddab	1.9	0.0
Kelp Crab	0.6	0.0
Algae type		
Saccharina latissima	57.1	72.5
Shell hash	27.1	12.5
Plocamium cartilagineum	0.0	7.5
Palmaria callophylloides	2.9	5.0
Cryptopleura ruprechtiana	7.1	0.0
Chondracanthus exasperatus	1.4	0.0
Ceramium pacificum	1.4	0.0
Gracilaria sp.	0.0	2.5

Photograph B1
Snorkel Surveys at University St, Pier 56 Is on the Right



Photograph B2
Looking South Under the Aquarium Pier, at a Lower Tide When the Seawall Ledges Are Exposed

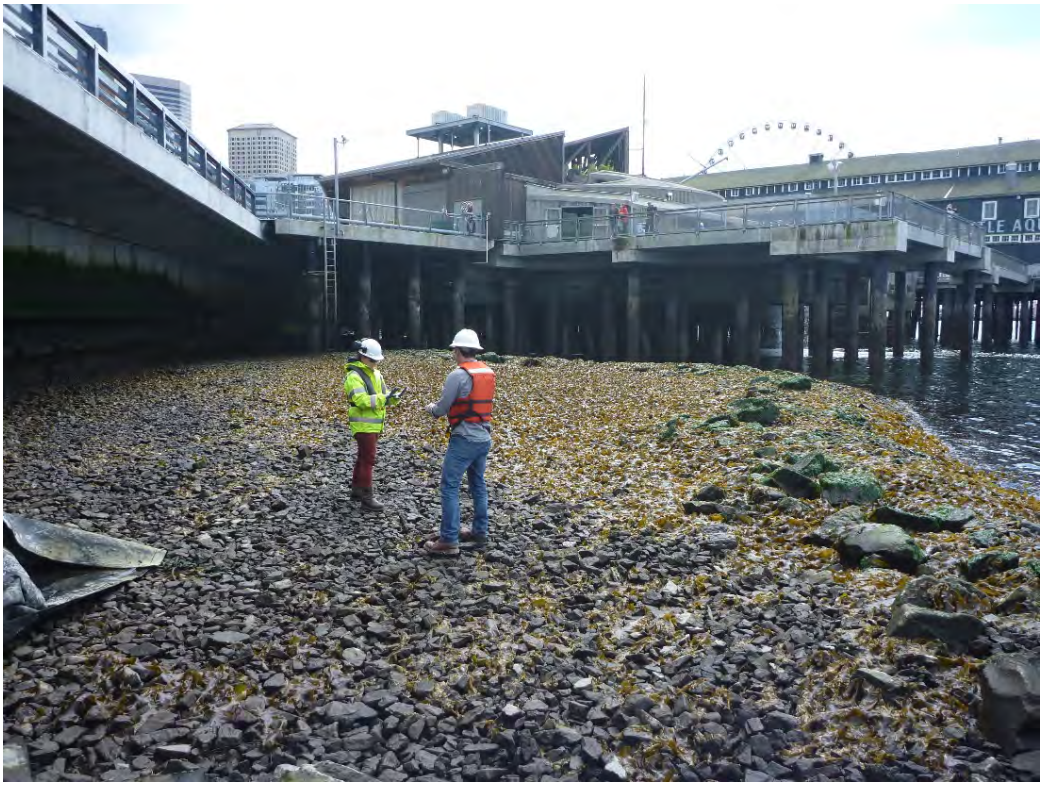
Photograph B3
Seawall North of the Aquarium, Showing the Terminus of the Phase I Rebuild During 2018

Photograph B4
Snorkel Surveys at the Olympic Sculpture Park Pocket Beach

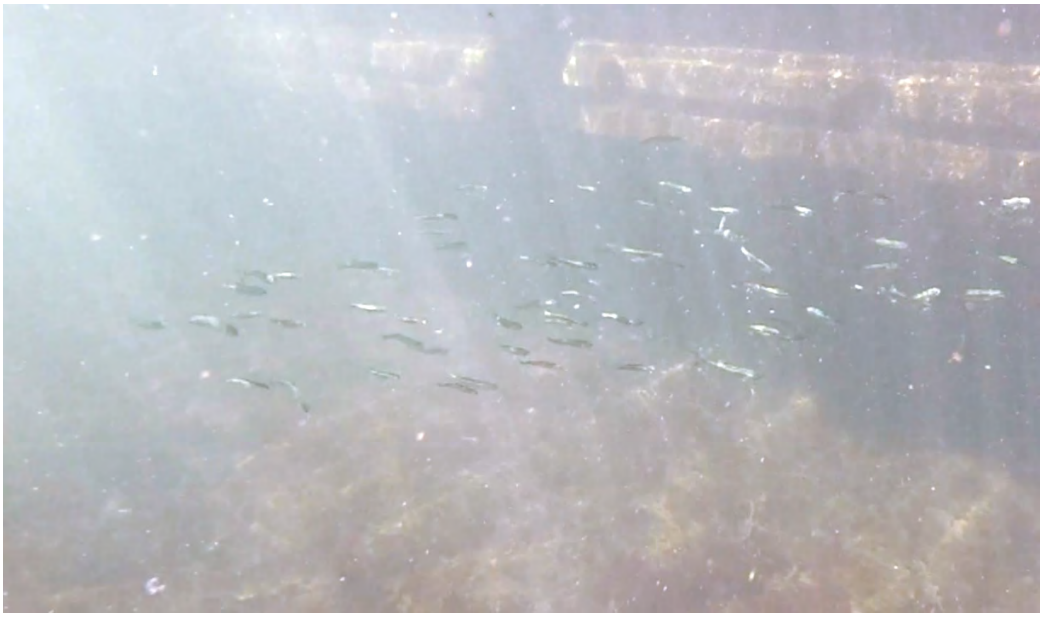
Photograph B5
Snorkel Surveys at the Olympic Sculpture Park Habitat Bench

Photograph B6
Light Measurements of Photosynthetically Active Radiation

Photograph B7
Extended Habitat Bench North of the Aquarium Pier, at Low Tide

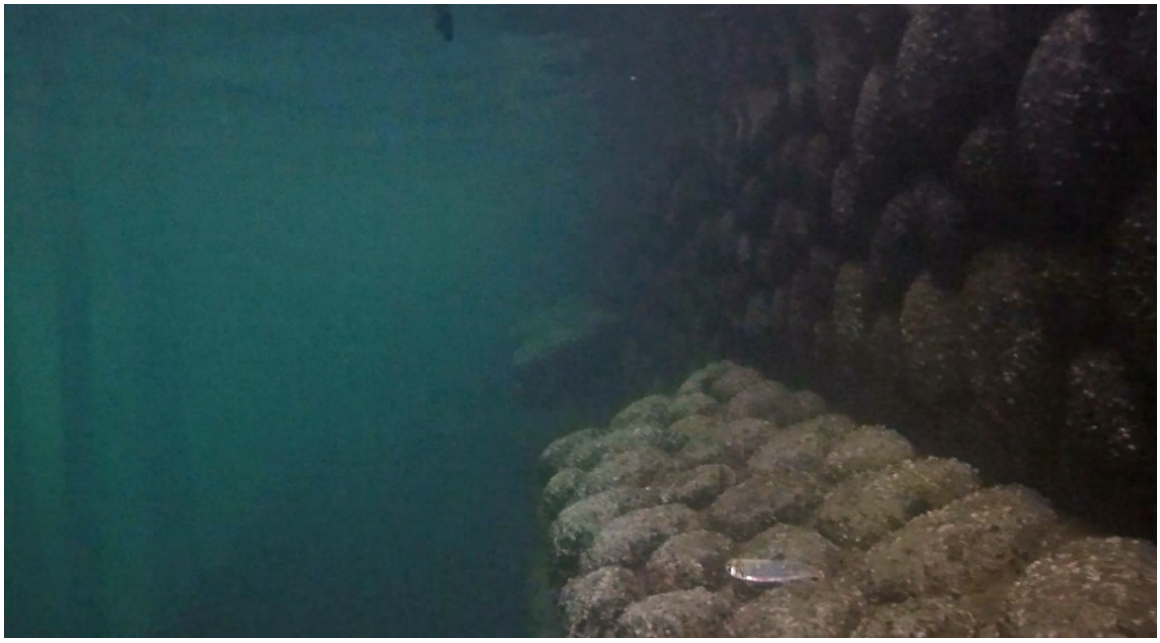


Photograph B8
A School of Juvenile Salmon Over the Habitat Bench at University Street in May 2018

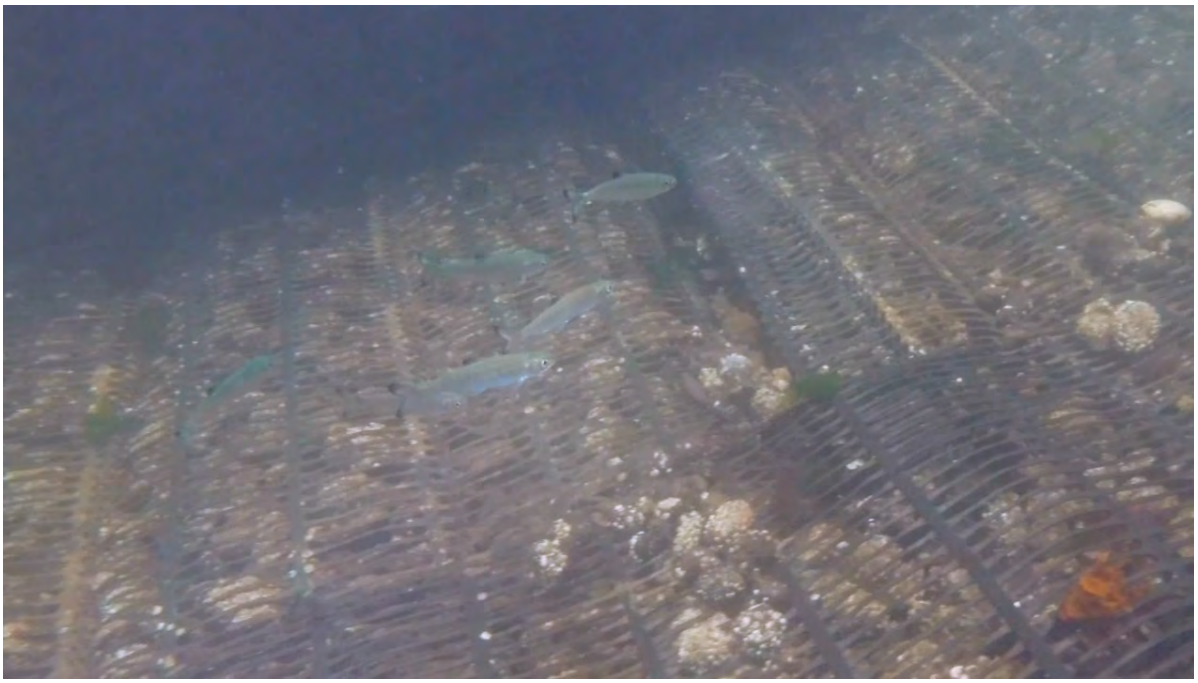


Photograph B9
A School of Juvenile Chum Salmon Observed Feeding Along the Seawall Under Pier 54 in April 2018

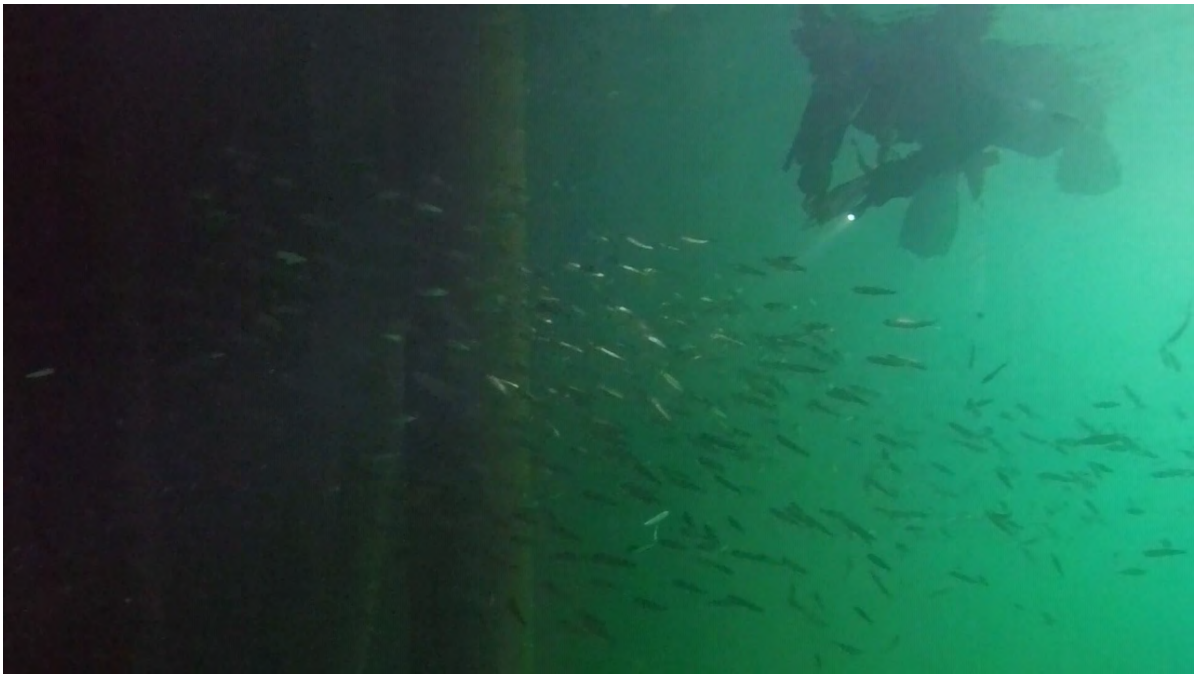
Photograph B10
A Juvenile Chinook Salmon Under Pier 54 in October 2018



Photograph B11
Juvenile Coho Salmon Under the Aquarium Pier Along the Base of the Habitat Bench in June 2018



Photograph B12
Herring Observed at the Edge of a Pier

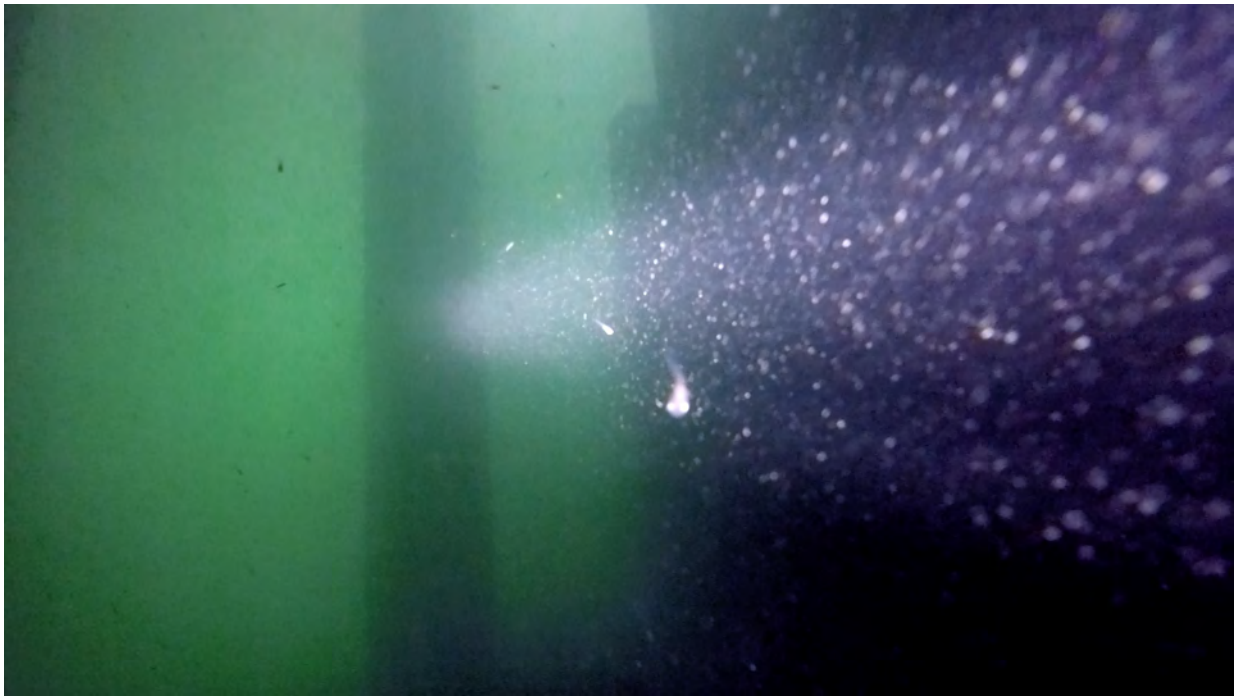


Photograph B12
A Quillback Rockfish Under Pier 54 in July 2018

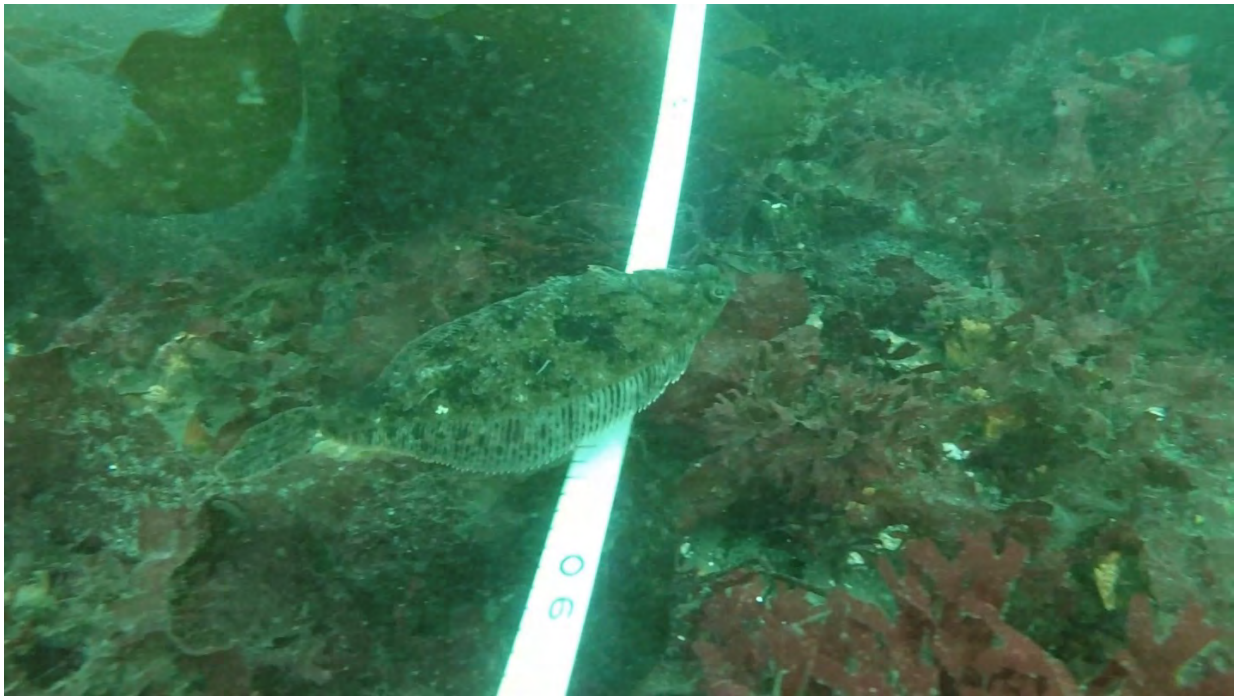
Photograph B13
Black Rockfish Observed in the Subtidal at the Olympic Sculpture Park Pocket Beach

Photograph B14
A Ratfish Observed at the Base of the Seawall Sheet Pile Wall

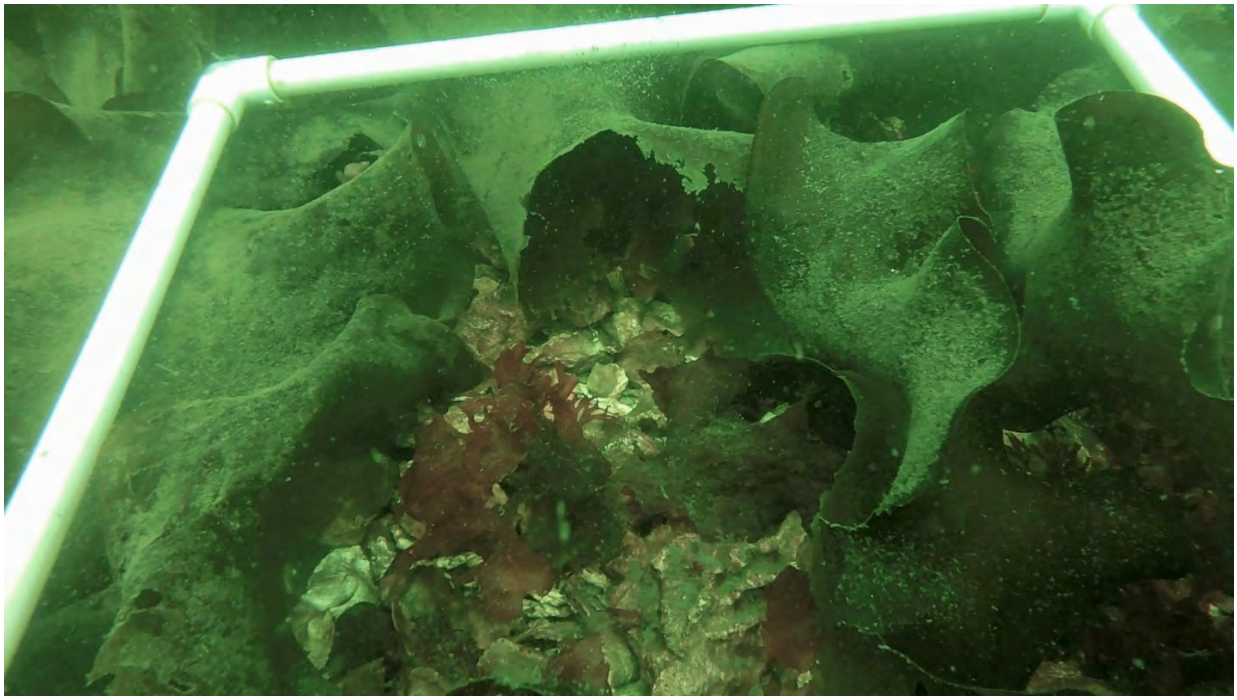
Photograph B15
A School of Larval Fish Observed Under Spring Street South Pier in July



Photograph B16
A Sanddab Observed at the Substrate Enhancement Off Waterfront Park

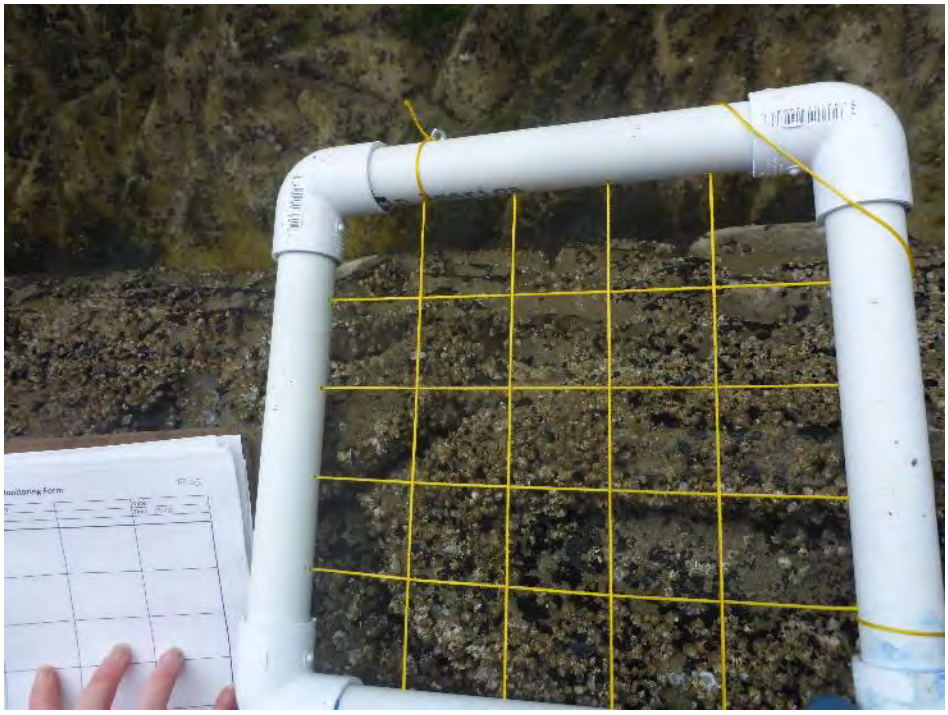


Photograph B17
An Algae Quadrat Survey at the Substrate Enhancement Off Waterfront Park

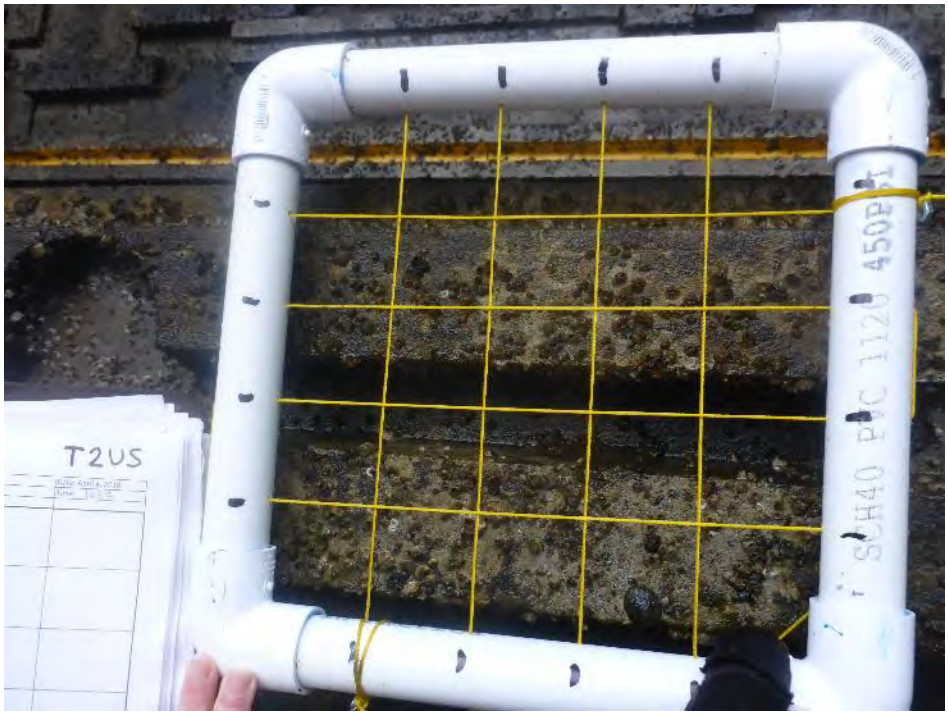


Appendix C
Invertebrate and Algal Surveys 2018
Year 1 Monitoring Photographs

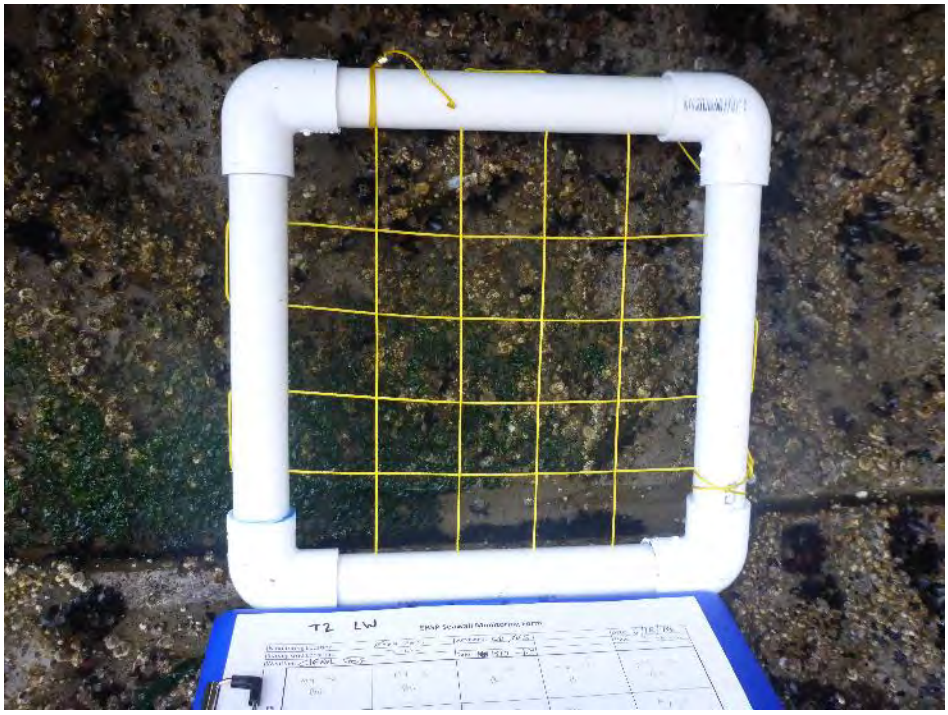
Photograph C1
April Monitoring Aquarium North Site Uncovered Quadrat T3US



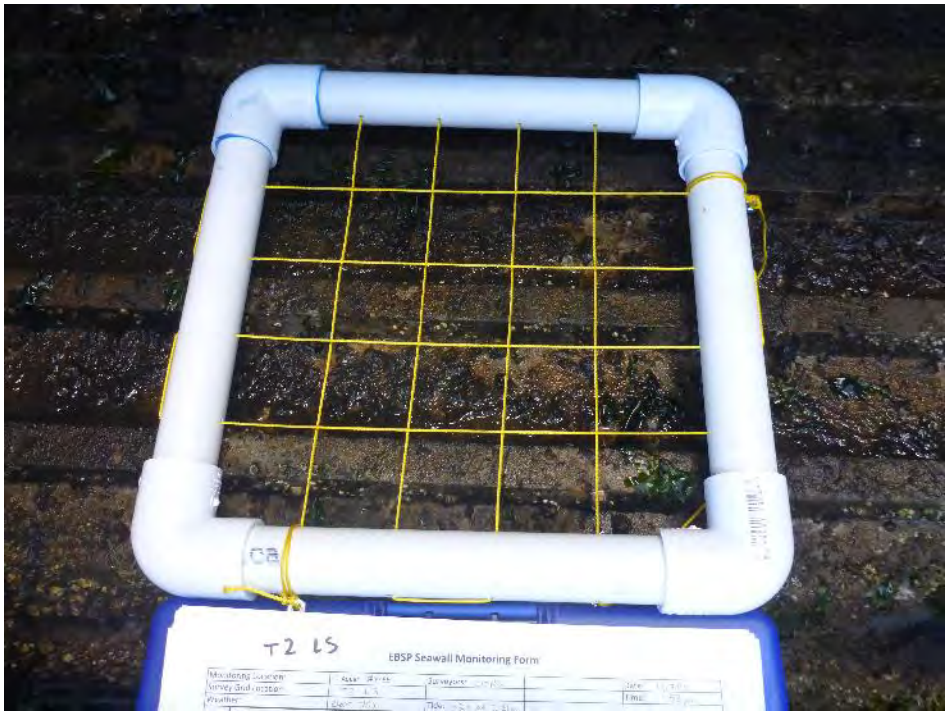
Photograph C2
April Monitoring Pier 55 Site Uncovered Quadrat T2US



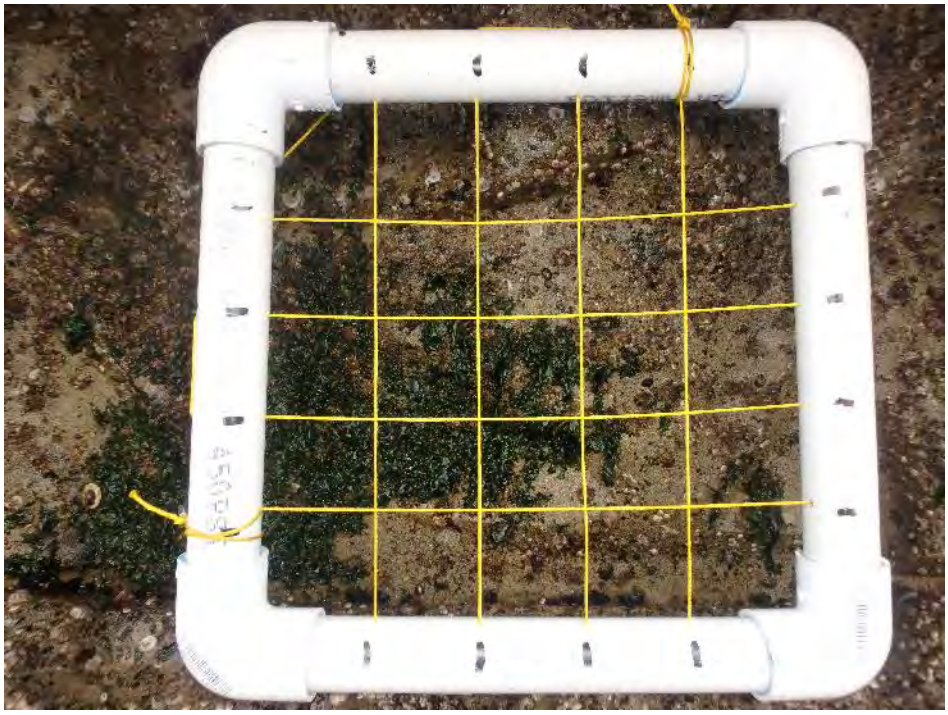
Photograph C3
June Monitoring Aquarium North Site Uncovered Quadrat T2LW



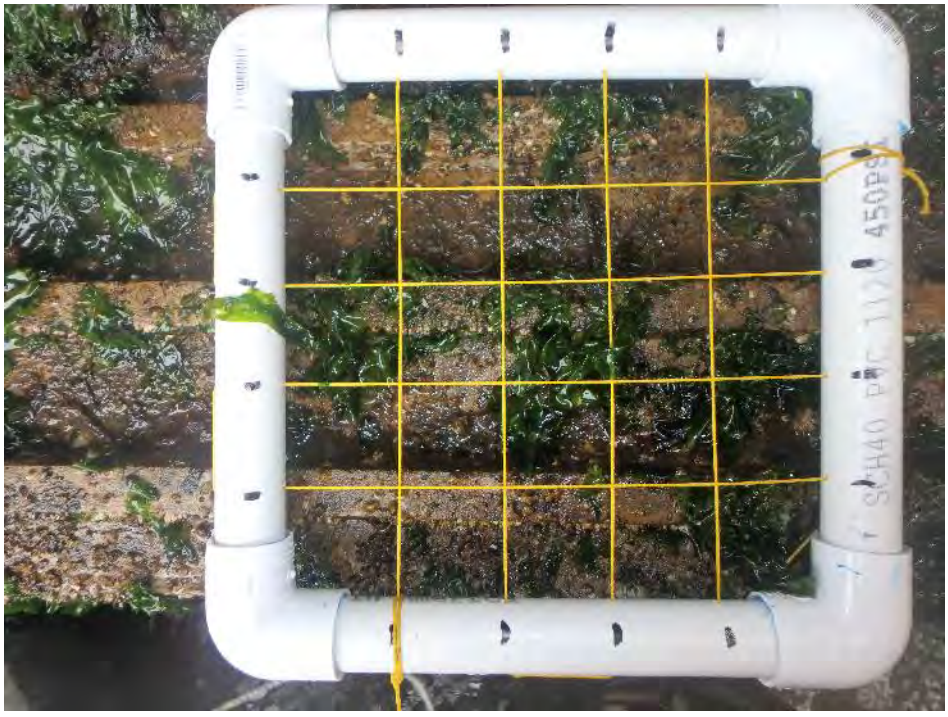
Photograph C4
June Monitoring Pier 55 Site Uncovered Quadrat T2LS



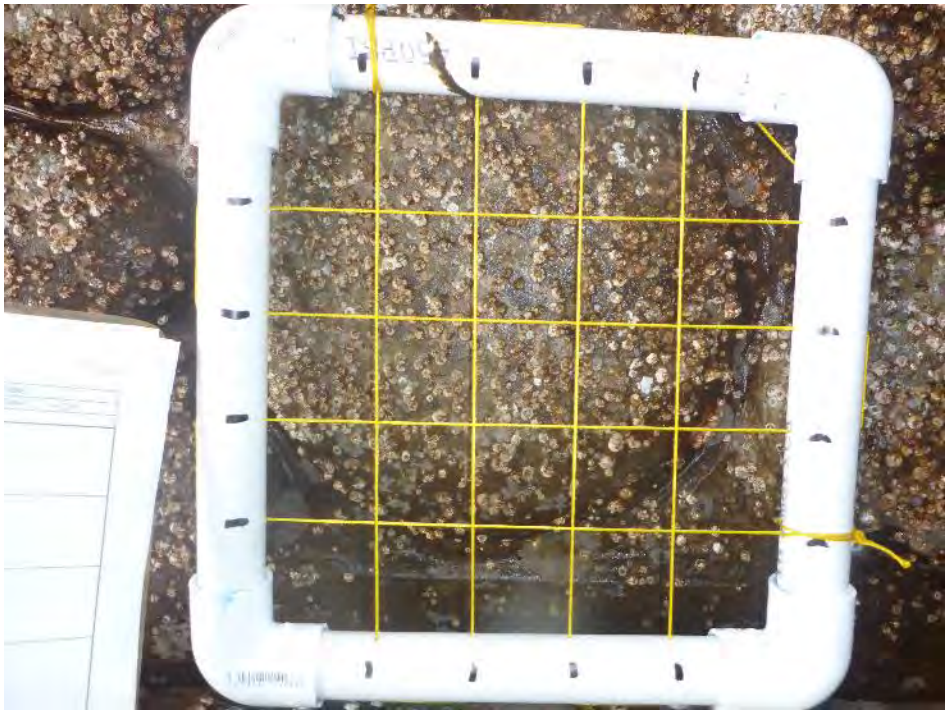
Photograph C5
August Monitoring Aquarium North Site Uncovered Quadrat T3LW



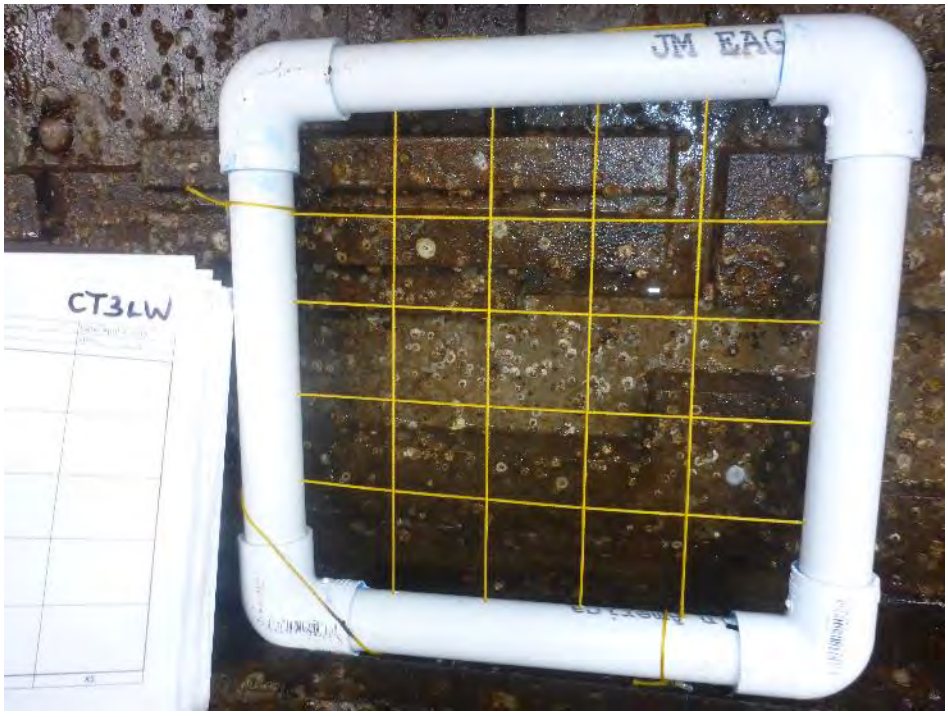
Photograph C6
August Monitoring Pier 55 Site Uncovered Quadrat T3LS



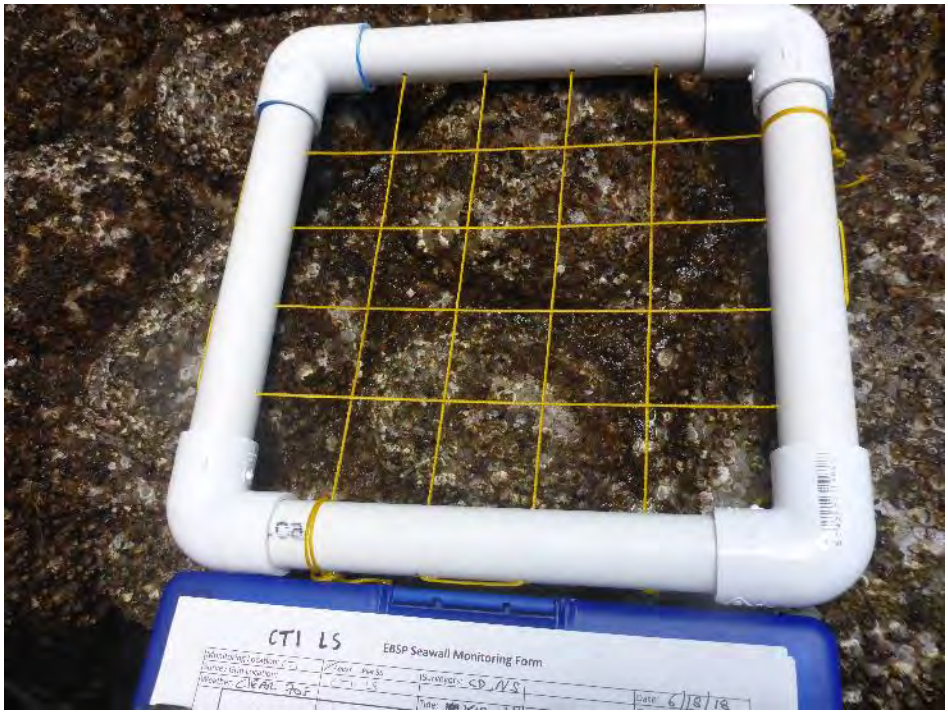
Photograph C7
April Monitoring Aquarium North Site Covered Quadrat CT1LW



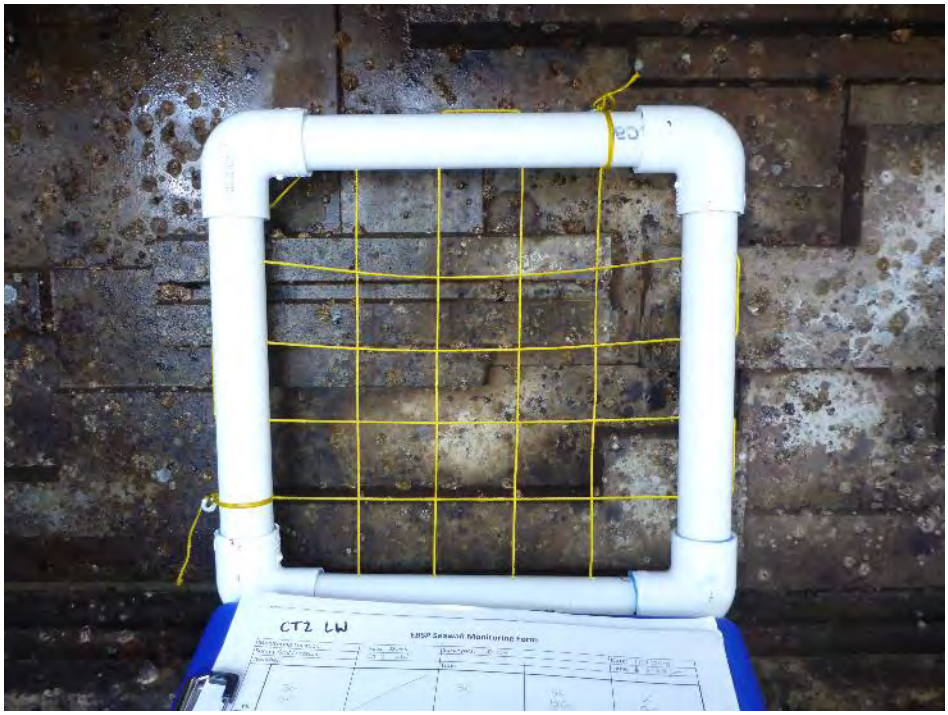
Photograph C8
April Monitoring Pier 55 Site Covered Quadrat CT3LW



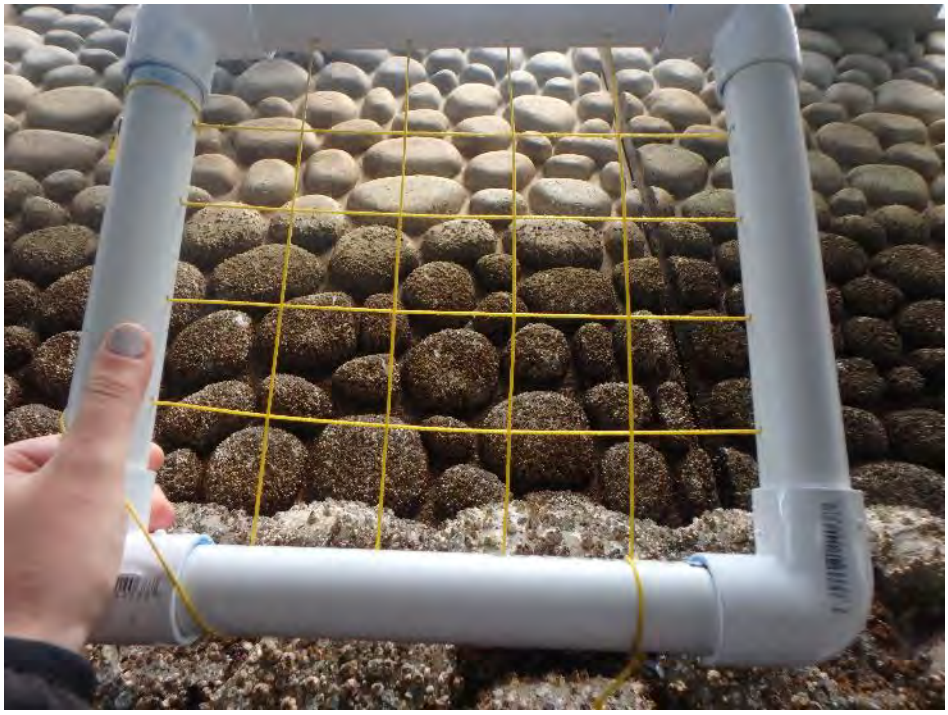
Photograph C9
June Monitoring Aquarium North Site Covered Quadrat CT1LS



Photograph C10
June Monitoring Pier 55 Site Covered Quadrat CT2LW

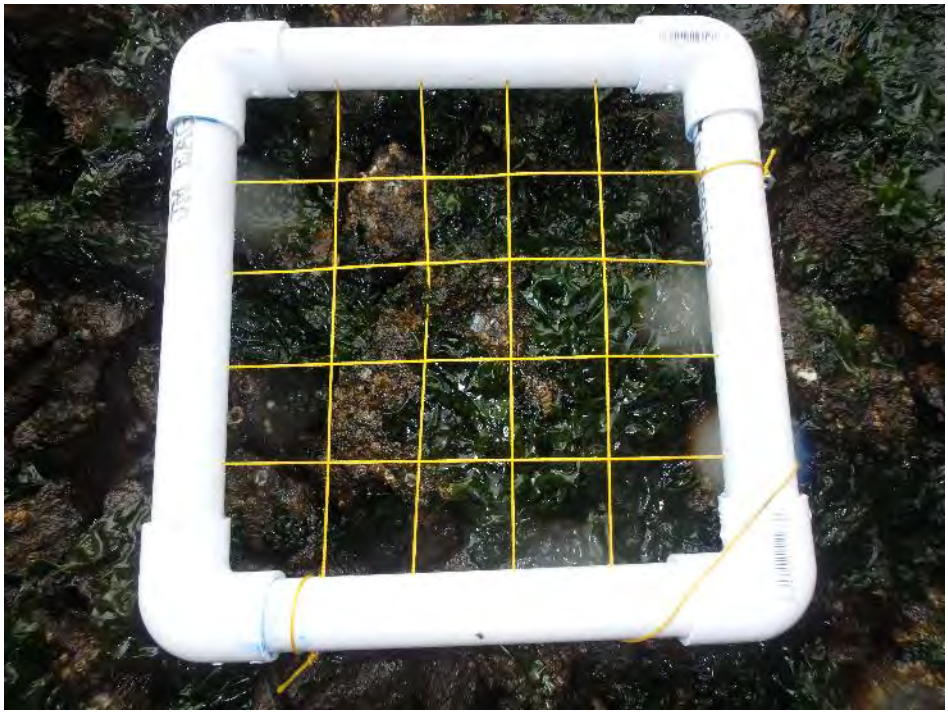


Photograph C11
August Monitoring Aquarium North Site Covered Quadrat CT2UW

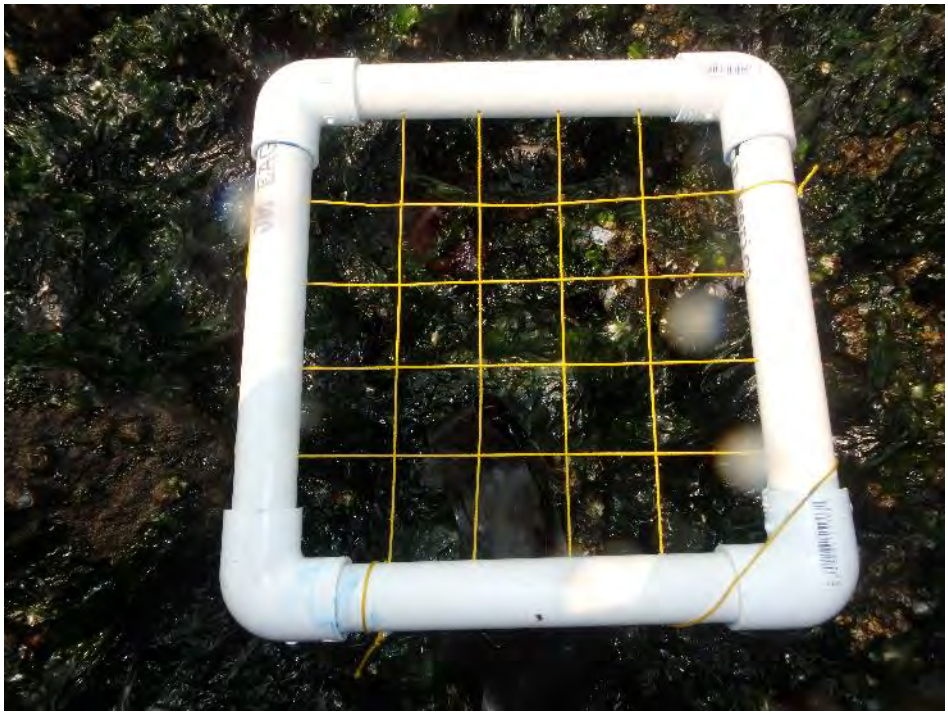


Photograph C12
August Monitoring Pier 55 Site Covered Quadrat CT3US

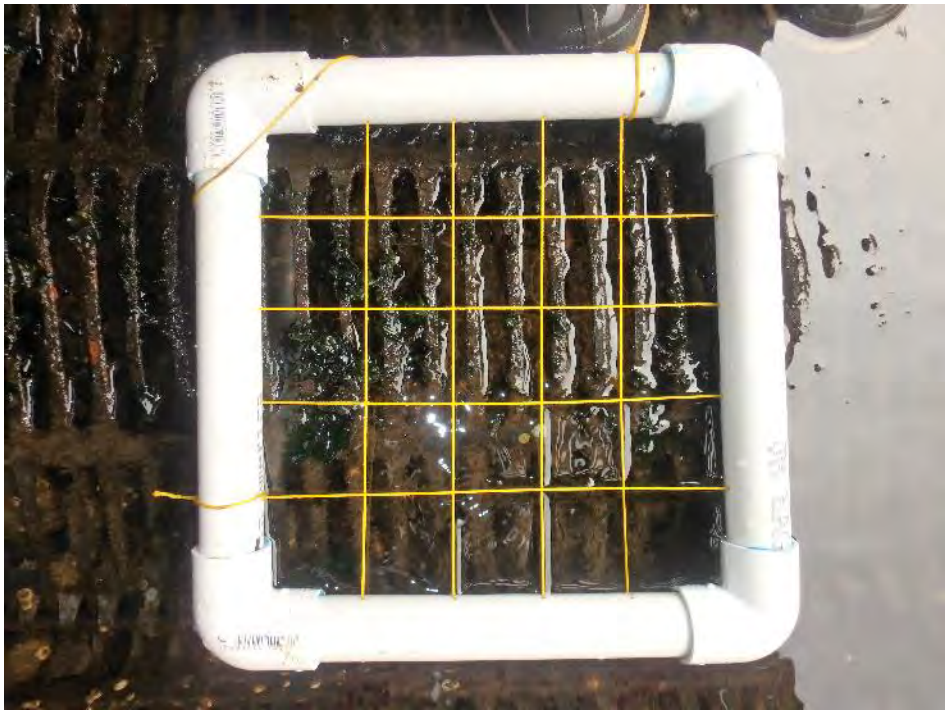
Photograph C13
August Monitoring Aquarium North Site Uncovered Bench Quadrat B3



Photograph C14
August Monitoring Aquarium North Site Uncovered Expanded Bench Quadrat B8

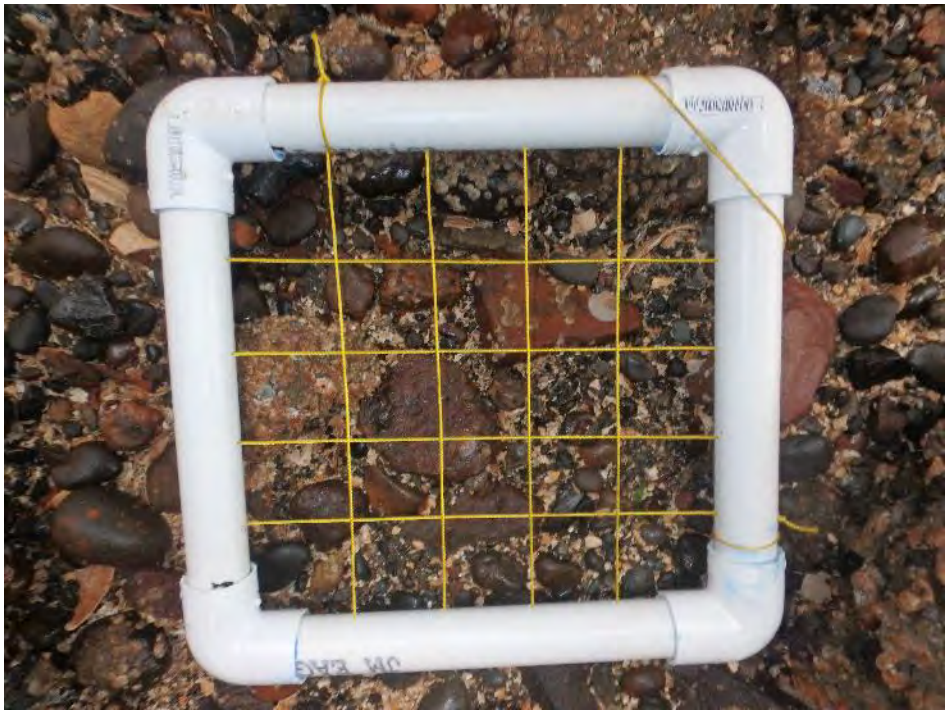


Photograph C15
August Monitoring Pier 55 Site Uncovered Bench Quadrat B2



Photograph C16
August Monitoring Aquarium North Site Covered Bench Quadrat B2

Photograph C17
August Monitoring Aquarium North Site Covered Expanded Bench Quadrat B7



Photograph C18
August Monitoring Pier 55 Site Covered Bench Quadrat B2